

## Pendergast, Jim

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**From:** Wendelowski, Karyn  
**Sent:** Monday, December 02, 2013 10:40 AM  
**To:** Srinivasan, Gautam  
**Subject:** FW: WOUS Connectivity: SAB Charge Questions  
**Attachments:** WOUS SAB Charge Questions Final v2.pdf; 11-06-2013 Science Committee Letter to Dr. Rodewald and Dr. Allen.pdf; 11-06-2013 Science Committee to Administrator Shelanski.pdf; TO 121\_ Post-Meeting Comments\_Final.pdf

Karyn Wendelowski  
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**From:** Kwok, Rose  
**Sent:** Tuesday, November 26, 2013 2:11 PM  
**To:** Wendelowski, Karyn  
**Subject:** FW: WOUS Connectivity: SAB Charge Questions

[FYI, not sure if someone forwarded this to you.](#)

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**From:** Downing, Donna  
**Sent:** Tuesday, November 26, 2013 11:07 AM  
**To:** Christensen, Damaris  
**Cc:** Kwok, Rose  
**Subject:** FW: WOUS Connectivity: SAB Charge Questions

As requested -- here's the SAB charge questions, science committee letter, and the peer review panel report, all in one tidy email.

-- Donna

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**From:** Pendergast, Jim  
**Sent:** Tuesday, November 26, 2013 9:23 AM  
**To:** Kaiser, Russell; Downing, Donna  
**Subject:** FW: WOUS Connectivity: SAB Charge Questions

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**From:** Frithsen, Jeff  
**Sent:** Monday, November 25, 2013 5:57 PM  
**To:** Pendergast, Jim  
**Subject:** WOUS Connectivity: SAB Charge Questions

Jim:

Two attachments: First, the Charge Questions provided to the SAB by the Agency. Second, the letter from the House Science Committee to the SAB Chairs. The suggested questions from the committee start on about page 4.

And to complete your reading pleasure for the evening, the third attachment is the House Science Committee letter to the OMB.

As always, let me know should you want to discuss.

Jeff

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# **Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence**

## **Technical Charge to External Peer Reviewers**

Understanding the physical, chemical, and biological connections by which streams, wetlands, and open-waters affect downstream waters such as rivers, lakes, and oceans is central to successful watershed management and to meeting water quality goals. It is also central to informing policy decisions that guide our efforts to meet these goals. The purpose of this Report, titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence* is to summarize the current scientific understanding of broadly applicable ecological relationships that affect the condition or function of downstream aquatic ecosystems. The focus of the Report is on small or temporary non-tidal streams, wetlands, and open-waters. Examples of relevant connections include transport of physical materials such as water or wood, chemical compounds such as nutrients or pesticides, movement of biological organisms such as fish or insects, and processes or interactions that alter material transport, such as nutrient spiraling. Materials reviewed in this Report are limited to peer reviewed scientific literature. Findings from this Report will help inform EPA and the U.S. Army Corps of Engineers in their continuing policy work and efforts to clarify what waters are covered by the Clean Water Act. As a scientific review, the Report does not consider or make judgments regarding legal standards for Clean Water Act jurisdiction.

The Report is presented in six chapters. Key findings and major conclusions are summarized in Chapters 1 (Executive Summary) and 6 (Conclusions and Discussion). Chapter 2 (Introduction) describes the purpose and scope of the document and the literature review approach. Chapter 3 presents a conceptual framework that describes the hydrologic elements of a watershed, the types of physical, chemical, and biological connections that link them, and watershed climatic factors that influence connectivity at various temporal and spatial scales. Chapter 4 surveys the literature on stream networks with respect to physical, chemical, and biological connections between upstream and downstream habitats. Chapter 5 reviews the literature on connectivity and effects of non-tidal wetlands and certain open waters on downstream waters. All terms are used in accordance with standard scientific meanings, and definitions which are in the Report glossary.

## TECHNICAL CHARGE QUESTIONS

### Overall Clarity and Technical Accuracy of the Draft Report

1. Please provide your overall impressions of the clarity and technical accuracy of the draft EPA Report, *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*.

### Conceptual Framework: An Integrated, Systems Perspective of Watershed Structure and Function

2. Chapter 3 of the draft Report presents the conceptual basis for describing the hydrologic elements of a watershed; the types of physical, chemical, and biological connections that link these elements, and watershed climatic factors that influence connectivity at various temporal and spatial scales (e.g., see Figure 3-1 and Table 3-1). Please comment on the clarity and technical accuracy of this chapter and its usefulness in providing context for interpreting the evidence about individual watershed components presented in the Report.

### Lotic Systems: Ephemeral, Intermittent, and Perennial Streams

- 3(a) Chapter 4 of the Report reviews the literature on the *directional (downstream) connectivity and effects* of ephemeral, intermittent, and perennial streams (including flow-through wetlands). Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of streams. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.
- 3(b) Conclusion (1) in section 1.4.1 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 3(a) above. Please comment on whether the conclusions and findings in section 1.4.1 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

### Lentic Systems: Wetlands and Open Waters with the Potential for Non-tidal, Bidirectional Hydrologic Flows with Rivers and Lakes

- 4(a) Section 5.3 of the Report reviews the literature on the *directional (downstream) connectivity and effects* of wetlands and certain open waters subject to non-tidal, bidirectional hydrologic flows with rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

- 4(b) Conclusion (2) in section 1.4.2 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 4(a) above. Please comment on whether the conclusions and findings in section 1.4.2 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

**Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including “Geographically Isolated Wetlands”**

- 5(a) Section 5.4 of the draft Report reviews the literature on the *directional (downstream) connectivity and effects* of wetlands and certain open waters, including “geographically isolated wetlands,” with potential for unidirectional hydrologic flows to rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.
- 5(b) Conclusion (3) in section 1.4.3 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 5(a) above. Please comment on whether the conclusions and findings in section 1.4.3 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

**Peer Review Meeting of EPA's Draft Report:  
Connectivity of Streams and Wetlands to  
Downstream Waters – A Review and Synthesis  
of the Scientific Evidence**

**Post-Meeting Comments**

**February 16, 2012**



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# Introduction

The U.S. Environmental Protection Agency's (EPA's) National Center for Environmental Assessment (NCEA) developed a draft report entitled "*Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*," for which Eastern Research Group, Inc. (ERG) organized an independent peer review under Task Order 121, contract EP-C-07-024. The purpose of the review was to identify any problems, errors, or necessary improvements to the report prior to being published or otherwise released as a final document. ERG was responsible for identifying and selecting the expert reviewers, managing the review, organizing and facilitating a one-day peer review meeting, and preparing the peer review summary report.

ERG identified and secured the services of eleven nationally recognized experts (Appendix C) to conduct this review:

- David J. Cooper, Ph.D., Colorado State University
- William G. Crumpton, Ph.D., Iowa State University
- Kenneth W. Cummins, Ph.D., Humbolt State University
- Walter K. Dodds, Ph.D., Kansas State University
- James W. La Baugh, Ph.D., U.S. Geological Survey
- Mark C. Rains, Ph.D., University of South Florida
- John S. Richardson, Ph.D., University of British Columbia
- Joel W. Snodgrass, Ph.D., Towson University
- Arnold van der Valk, Ph.D., Iowa State University
- Mark S. Wipfli, Ph.D., U.S. Geological Survey
- <sup>1</sup>William R. Wise, Ph.D., University of Florida

ERG provided the reviewers with a letter of instruction and the technical charge, which asked for their comments on the various aspects of the draft report. In the first stage of the review, the experts worked individually to prepare written pre-meeting comments, which were provided to all reviewers and EPA prior to a one-day peer review meeting. In the second stage, ERG convened the one-day meeting on January 31, 2012, at a venue in Washington, DC (Appendix B provides a copy of the agenda). Ten of the eleven reviewers participated in the workshop; Dr. Wise was not able to attend.

The meeting was closed to the public and considered an internal EPA deliberative process. Observers from EPA and the U.S. Army Corps of Engineers attended to listen to the discussions. The list of observers is provided in Appendix D. The meeting process was facilitated by Ms. Kate Schalk, of ERG, and the technical discussions were led by Dr. Walter Dodd. At the close of the meeting, the reviewers developed some brief highlights of their discussions, which follow this introduction. After the meeting, reviewers revised their pre-meeting comments to reflect their views as they had evolved based on the meeting discussions. The reviewers' final post-meeting comments are provided in this report. These comments reflect the individual opinions of the reviewers.

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<sup>1</sup> Since Dr. Wise was unable to attend the workshop, only his pre-meeting comments are included.



## **Reviewers' Highlights from Meeting Discussions**

### **Peer Review Meeting for EPA Draft Report: Connectivity of Streams and Wetlands to Downstream Waters - A Review and Synthesis of the Scientific Evidence**

The reviewers' highlights were prepared by the peer reviewers in the closing session of the peer review meeting held on January 31, 2012. Dr. Walter Dodds, the technical chair, led the discussions. Post-meeting, peer reviewers reviewed the highlights produced onsite and provided any clarifications or edits, which were considered and incorporated into paragraph below.

We applaud the authors for a document that has integrated a diverse literature and in principle we agree with the overall conclusions of the report. Chemical, physical and biological connectivity are common features of streams and wetlands. This connection can have clear influence on downstream waters. The case for the influence is strongest for streams (headwaters including ephemeral and intermittent) and for wetlands on flood plains. The evidence for the influence is not as strong for some wetland types but many are strongly connected to downstream waters. The introduction needs an overarching spatial and temporal conceptual model of the gradients of connectivity across landscapes, and the physical and ecological processes that support connectivity. The introductory framework of source, sink, refuge, lag, and transformation should be followed throughout the document. The document should be reviewed for consistent and accurate terminology and should employ a more appropriate classification scheme for wetlands. The aggregate downstream influences of streams and wetlands should be considered in the introduction and the individual chapters (or in its own chapter), and such consideration should help guide the synthesis. The last section of the report should provide a truly synthetic statement about the connectivity and downstream effects of non-navigable waters.



## **Post-Meeting Responses to Charge Questions**



**Introductory Comments (Not all reviewers provided introductory comments.)**

Reviewer	Comments
<b>Cooper</b>	<p>The authors of the report have done an excellent job of bringing together a huge and scattered literature. The report was difficult to read due to its length, and I find it hard to imagine that most people will use this anything other than a reference document. The literature review indicates that our knowledge of hydrologic connections between tributary streams and wetlands and waters of the U.S. is conceptual, with case studies in several portions of the U.S. but large regions, such as western mountains, and southwestern deserts, where little is known. A few things should be clarified to make this report more useful.</p> <p>The report focuses on what we know. I would suggest that each section of the report must have a discussion of what is unknown or uncertainties about connections, functions, and what future research is needed to support our understand of these processes. The report gives the impression that we know most of what is needed to understand and regulate these tributaries and wetlands. I think this is only partially correct.</p> <p>The temporal aspect of these jurisdictional identifications should be clarified. For example jurisdictional wetlands, under S404, must have flooding or soil saturation for a certain number of days during the growing season. One day of saturation is insufficient, but 14 days is typically sufficient. However this report does not clarify how many hours, days, or weeks per year a tributary must flow into a water of the U.S. to be considered jurisdictional. For an ephemeral stream in Arizona that is tributary to a water of the U.S. is it sufficient if this stream flows on average 1 or 2 days per year, and in some years never flows? For a non-continuous wetland how often does the surface or subsurface connection have to occur? How often do the cited ecological functions, i.e., sediment retention, have to occur? These concepts are critical to have a definitive and objective jurisdictional approach. After the panel meeting I'm still unsure how to include every single channel across the U.S. into a single framework of ecological functioning.</p> <p>Methods for measuring ecological function should be reviewed and included in this report. The U.S. has spent millions of dollars supporting the Adamus methods, Wetland Evaluation Technique, HGM and other approaches that all have been extensively peer reviewed and used in the U.S. I include a few key references at the end of my comments. Methods such as these are critical for inclusion because any field activities would need a framework for how to evaluate function or nexus between any stream or wetland and a downstream water.</p> <p>I understand the importance of identifying "similarly situated waters" as a way of extending our understanding beyond single sites. However, the geomorphic context of such sites must be carefully evaluated. This is no simple matter and no method for doing such comparisons is presented in the report.</p> <p>The definitions used in this report need significant improvement. For example wetlands, riparian, floodplain, non-riparian wetland, etc. are all in need of greater clarification. I suggest not using the Cowardin et al. (1979) definition of wetland in this report. The U.S. has regulatory definitions of wetlands that should be used as these definitions have been</p>

	<p>peer reviewed innumerable times. Riparian is more a term of art than science. The classical definition is that it includes areas adjacent to flowing water, i.e., streams. I'm not sure how floodplains differ from riparian areas, or how riparian areas are defined or bounded.</p> <p>The overall report needs an ending synthesis, not summary at the end of the document.</p> <p>The example provided for Southwestern streams, the San Pedro river is not a representative stream. Much attention has been paid to the San Pedro, making it the most studied stream in the SW because it is unique. It flows north from Mexico, has many perennial reaches, almost all of the river has shallow ground water, and most has well developed riparian forests. In contrast most streams in the region are ephemeral, few are intermittent and only a very few are perennial. Few have shallow ground water. I would suggest that if the San Pedro is retained, than a second example system is presented. One of our published papers (Shaw and Cooper 2008) published in the Journal of Hydrology may provide a different representative ephemeral stream baseline. I have attached this in case EPA authors wish to use this or have not seen it.</p> <p>CLASSIFICATION: I think that a classification of U.S. wetlands would be helpful as a unifying theme for the document. There are many attempts to classify wetlands and regions including EPA's ecoregion concepts from Omernick et al., in its many documents. Each region has distinctive wetland types, and it would be nice to discuss each type and issues related to connectivity, and functions that effect downstream waters. In addition, the book on Wetlands of the U.S. should be published this spring/summer by University of California Press. The wetland types or chapters within could also provide a good framework for discussing issues related to connectivity, and uncertainty in connections and ecological functions. Another potential is to organize around HGM wetland types, such as depression, slope, etc. although there is great variance through the U.S. on how basin/depression wetland function.</p> <p>Beavers are a key part of the biotic/hydrologic connection for streams and riparian areas throughout the northern hemisphere, and even the southern hemisphere. It would be important to mention this important driver of connections and exchange of water, materials and biota between streams and wetlands.</p> <p>I also ask EPA to remove concepts suggesting that riparian areas are "transition zones". This is completely false and misleading. Riparian zones support distinctive biota, hydrological and ecological processes that distinguish them from uplands or aquatic ecosystems.</p> <p>The concept of "channel origin wetlands" is quite foreign. I think that EPAs concept was that sites of ground water discharge would support wetlands that would feed into downstream waters. However, hydrologically, many wetlands are flow through, with ground water flowing in, and ground water flowing out, and no surface water other than in the wetland. This concept is important for the prairie potholes, but also anywhere else that basin wetlands are prevalent.</p> <p>Many figures could use revision as listed below:</p> <p>Figure 3-2, does not show ground water flow, and little of the landscape is connected to the channels.</p>
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	<p>Figure 3-7, panel a shows a stream that virtually dries up, and it's not very representative for perennial streams in most of the US.</p> <p>Figure 3-6, all of these panels show a river connected via ground water inflow. Please expand these concepts to include rivers that are not connected to adjacent lands via ground water. Either they are losing, or disconnected. Same comment for Figure 3-13 and Figure 3-16.</p> <p>Figure 3-5, the scale on this is very poor. For example showing a regional GW flow that is just a tad different from local or intermediate GW flows is inaccurate.</p>
<b>Dodds</b>	<p>This report is generally very well written. It clearly makes the case for connectivity of both streams and wetlands to downstream waters based on many published sources of information. I particularly like the framework of source, sink, refuge, transformation and lag to identify key functions. This approach really allows the issue at hand to be very clearly explored. However, this framework is not really clearly delineated throughout the document, and I think the document would be strengthened by some slight reorganization along these lines.</p> <p>In a broad sense, the document indicates that the burden of proof should be on those claiming a stream or a wetland is not connected to downstream waters. The verbiage on lines 5617-5623 is a good example of this concept and potential problems with assuming lack of connectivity.</p>
<b>Richardson</b>	<p>This is a very nicely written and comprehensive document. The regulatory context is explained very well as background to understanding the intent of the report. The definitions of terms such as riparian, wetland, connection, etc., are given so that the details are explicit. The case studies approach to giving explicit examples and how their connections would be interpreted is a good idea and very effective, especially given that the examples were for systems that could be questioned about their connectedness with navigable waters, depending upon interpretation of the terms of the legal opinions. The figures are effective in illustrating principles and evidence.</p> <p>The conceptual framework with source, sink, lag, transformation and refuge (Leibowitz et al., 2008) is a nice idea, and it provides a good way to educate readers about the kinds of processes, and how they are influenced by spatial scales and temporal scales. However, this framework doesn't seem to be used throughout the stream examples (chapter 4). For instance, the example from the prairie streams doesn't mention these conceptual components much. The examples given about streams provide good examples demonstrating the processes that connect the small tributaries to downstream reaches, but it would be useful to better link these with the conceptual framework. The wetland chapter (5) does a better job of bringing these model terms into the description throughout that section.</p> <p>A "non-riparian" wetland (NRCWs – non-riparian and channel origin wetlands) seems an odd term, but I wonder if non-floodplain wetland might be better? The definition of riparian area as transitional between aquatic and terrestrial (P.26) makes it difficult to know when one might no longer be in transition across a floodplain, for example. Gregory et al.'s (1991) definition of riparian area would make it difficult to have a non-riparian wetland,</p>

	<p>unless this simply means not in the riparian area of a navigable-in-principle stream. The consistent use of floodplain and riparian as a combination term (e.g., L.590) makes me think that floodplain might be sufficient (later in Chapter 5 the use of “riparian/floodplain” makes them seem interchangeable). Chapter 5 appeared confusing as to whether wetlands were floodplain/riparian (P.212) or NRCWs at some points, but maybe these were to apply to all wetlands. At one point (L. 594) it says that both floodplain and NRCWs could be geographically isolated, but I am having difficulty seeing how this definition of surrounded by uplands could apply to floodplain wetlands.</p> <p>It seems like the methylation of mercury is better explained on P.233 than it is earlier in the chapter when mercury is discussed for NRCWs. Perhaps the explanation could be moved up to provide the detail when it is first mentioned.</p> <p>Coastal streams entering the oceans, and not a navigable-in-principle river, might not be covered under the definitions used in this report.</p> <p>Some sections seem to convey a lot of information that is somewhat peripheral to the issue at hand, for instance, it is not clear what the material on P.136-137 contributes to the understanding of whether this is a navigable-in-principle stream or tributary to a navigable-in-principle stream.</p> <p>It wasn't clear what the distinction between Carolina Bays and Delmarva Bays is, or whether it is solely geographic. The Glossary did not help with that.</p> <p>It appeared to me that the Executive Summary was a little long, depending upon who the anticipated audience for this might be. There is a lot of territory to cover, and perhaps the regulators will need this much information. The summary is sound, so I am not criticizing the content, just the length.</p> <p>I am still a bit vague on the opinion of the other 4 justices that were not included in the Scania or Kennedy statements. I think that the other opinion(s) should be explained a little further.</p> <p>I like the idea of proportional benefits from non-navigable waters, as expressed in the Leibowitz et al. (2008) paper. Moreover, the idea that these benefits may be realized or potential benefits is a helpful way to think about the capacity of a source system to provide benefit. However, these benefits may not be linear with respect to concentration or rates in their contributions. For instance, some nitrogen released to downstream would be beneficial, whereas too much would be detrimental, and the relative benefit might vary in a way that not add up so nicely.</p> <p>Some authors, such as Stan Gregory (Oregon State U), are trying to discourage the use of “large woody debris” (L.1780), and in preference use “large wood” to avoid connotations of waste material given what we know about the important geomorphic and cover roles of large wood in streams and wetlands.</p> <p>The “Draft guidance ...” document appears to be for field staff, and perhaps a decision tree or flow diagram might be useful to distinguish classes of entities and then refer from that to detailed guidance. It seems like a hefty document to plow through to determine what kind</p>
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	<p>of system they are looking at. Of course, all the document is needed, but some way to sort through it quickly might be helpful.</p> <p>Editorial:</p> <p>L.3135 – change “particularly” to “particular”</p> <p>L.4929 – family Chironomidae, not subfamily</p>
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1. This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.

a) Are these conclusions supported by the scientific evidence?

Reviewer	Comments
Cooper	The conclusions are supported in part. Clearly if hazardous waste is placed into an ephemeral desert stream, the material will likely flow to a water of the U.S. on some time scale, likely years to decades.
Crumpton	<p>The conclusion that all streams are physically and chemically connected to rivers is well supported if we incorporate a minor modification that seems consistent with the body of the report. Specifically, it is possible to have losing streams that are not hydrologically connected to downstream waters via channels and perhaps not chemically or biologically connected. I infer this as the basis for the report excluding certain channel origin wetlands that feed losing streams. The exception of certain wetlands spilling to losing streams as potentially not being connected to downstream waters is introduced in the <i>Executive Summary</i> on page 13, lines 285-289 and repeated numerous times throughout document.</p> <p>285 ephemeral streams that originate from them). In non-riparian wetlands that are not  286 connected to the river network through a stream channel (i.e., geographically isolated  287 wetlands and wetlands that spill into losing streams), connectivity varies geographically  288 within a watershed and over time, making it difficult to generalize about their connections  289 to, or isolation from, downstream waters.] The literature we reviewed does not provide</p> <p>With the exception of certain losing streams that may lack a connection to downstream waters, the conclusion that at least collectively streams exert a strong influence on the character and function of downstream waters is well supported. The report illustrates this through estimates of the fractions of river flow and material loads (nutrients, carbon, etc.) that originate in streams.</p> <p>The report provides sufficient coverage of the relevant peer-reviewed literature on physical and chemical connections of streams to downstream waters with the possible exception of losing stream reaches (i.e., the possible isolation of losing reaches from downstream waters). Given the apparent inference in the report that certain losing stream reaches may not be connected to downstream waters, this particular concept should be clarified and supported with relevant literature.</p> <p>In general, the literature was cited and summarized appropriately. The report does a particularly good job in summarizing the complex nature of stream networks including the major components and their spatial and temporal dynamics.</p> <p>I offer no response with respect to the questions involving biological connections of streams to downstream waters as this is outside my area of expertise.</p>

<b>Cummins</b>	The conclusions are supported by the scientific evidence.
<b>Dodds</b>	For the most part, these conclusions are supported by the scientific evidence. There are a very few cases, where streams flow from wet areas (e.g., mountains) into dry areas (e.g., deserts), where streams might not connect to any downstream waters. However, these sites are the exception, not the rule.
<b>La Baugh</b>	<p><b>Note: underlined text identifies critical or essential suggestions.</b></p> <p>The general synthesis of the cited literature provided in the report supports conclusion 1. The document, however, includes some conceptual inconsistencies that would benefit from resolution and clarification. These items are noted below.</p> <ul style="list-style-type: none"> <li>• <b>Page 30, lines 634 to 635 – Figure 3-5</b> – Because the wetland is at a location where there is a break in slope, the absence of groundwater interaction with the wetland is remarkable. The fact there are local, intermediate, and regional flow systems is illustrated by Toth’s work [see figure A-4 in Winter et al. (1998) <a href="http://pubs.usgs.gov/circ/circ1139/pdf/circ1139.pdf">http://pubs.usgs.gov/circ/circ1139/pdf/circ1139.pdf</a> ]. Other figures in Winter et al. (1998) provide cross section diagrams of flow to rivers that includes arrows for local and regional flow, such as for a riverine valley – Figure 22 on page 39.</li> <li>• <u>If the intent of the use of a figure in this part of the introduction, however, is to indicate flow from groundwater follows shallow, intermediate, and deep flow paths prior to discharge to a river, each representing different amounts of time in transit, a better figure would be something like Figure 3 from Winter et al. (1998).</u> An additional reference for the fact that groundwater representing different flow paths and times in transit discharge to a stream is Modica, E. 1999, Source and age of ground-water seepage to streams. U.S.Geological Survey Fact Sheet 063-99, 4 p. <a href="http://pubs.usgs.gov/fs/1999/0063/report.pdf">http://pubs.usgs.gov/fs/1999/0063/report.pdf</a></li> <li>• <b>Page 33, lines 680 to 682</b> – Are all alluvial aquifers referred to as hyporheic zones? The parenthetical statement equating hyporheic zone with alluvial aquifer is problematic. <u>To avoid confusing readers, the statement equating hyporheic zone with alluvial aquifers could be deleted.</u></li> <li>• <b>Page 38, lines 768 and 769</b> – <u>The phrase “aquifers contract” is unusual. Does the formation that is capable of conducting groundwater contract? Perhaps what was meant was that groundwater levels decline.</u></li> <li>• <b>Page 42, line 826</b> – The phrase “This water has can alter the geomorphology...” is awkward. Revision for clarification would be useful.</li> <li>• <b>Page 62, line 1195, and page 63, Figure 3-17</b> – <u>Use of the term ‘impermeable aquifer’ is incorrect.</u></li> </ul> <p><u>An aquifer by definition is “A body of rock that contains sufficient saturated permeable material to conduct ground water and to yield economically significant quantities of water to wells or springs.” Margaret Gary, Robert McAfee Jr., and Carol L. Wolf, editors, 1972, ‘Glossary of Geology’, American Geological Institute, Washington, D.C.; or “An</u></p>

	<p><u>aquifer is a formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells or springs.” S. W. Lohman and others, 1972, Definitions of selected ground-water terms- Revisions and conceptual refinements, U.S. Geological Survey Water-Supply Paper 1988, 21 p.</u></p> <ul style="list-style-type: none"> <li>• <b>Page 62, lines 1194 to 1200</b> – <u>It would be useful to revise the paragraph to clarify the key points being made about flow systems while being consistent with correct use of technical terms. It is not at all clear why the explanation includes reference to intermediate or regional flowpaths. Intermediate and regional flow paths occur as a function of groundwater basin depth to width ratio (Toth, J.A., 1963, A theoretical analysis of ground-water flow in small drainage basins. Journal of Geophysical Research, v. 68, p 4795-4811). Also, surface waters with low permeability deposits in area of high topographic relief can receive water from beyond the local surface watersheds (Winter et al., 2003, Where does the groundwater in small watershed come from? Ground Water, v. 41, p. 989-1000).</u></li> <li>• <b>Page 135, line 2731</b> – <u>Because vagility has the same meaning as capability of movement, is there any reason to use the term? Consider deleting vagility to simplify the text.</u></li> </ul>
<p><b>Rains</b></p>	<p><b>SUMMARY</b></p> <p>The conclusions are supported by the scientific evidence provided. This is the easiest task for the authors, because hydrological and ecological connectivity are fundamental tenets for these systems. However, I do have comments regarding some flaws and/or inadequacies in the scientific evidence provided as justification. (See, also, the detailed comments related to the conceptual framework in the section titled “Additional Reviewer Comments” below.)</p> <p><b>DETAILED COMMENTS</b></p> <p>General Comment: There is incomplete discussion of perennial tributaries that are disconnected from perennial mainstems by seasonal or ephemeral reaches. This commonly occurs in the West, where tributaries are often perennial in the mountains but lose rapidly and are intermittent or ephemeral on the alluvial fans (Izbicki 2007). Furthermore, there is no discussion at all of closed basins that lack any kind of navigable water at all. I don’t know about now, but I do know that a few years ago, the U.S. Army Corps of Engineers (Corps) Albuquerque District was calling these isolated basins not subject to federal jurisdiction under the Clean Water Act (Parenteau 2004-2005). This document should provide clearly articulated evidence, one way or another, toward connectivity in these contexts to better enable decision-makers to resolve this policy conflict. Nadeau and Rains (2007) foresaw this, and separated this case out for special attention. Something like that might be called for here, too.</p> <p>1. 1492-1537: This entire section would be greatly strengthened if you would include a review of some of the papers that show that hydrological and ecological connectivity are central tenets of stream hydrology and ecology. Some examples might include the Four-</p>

<p>Dimensional Nature of Lotic Ecosystems (Ward 1989), the River Continuum Concept (Vannote et al., 1980), the Serial Discontinuity Concept (Stanford et al., 1988, Ward and Stanford 1995, Stanford and Ward 2001), and the Featured Collection of JAWRA devoted to this very topic (Nadeau and Rains 2007 and references therein; Note: The Nadeau and Rains 2007 referenced in this specific instance is different than the Nadeau and Rains 2007 referenced throughout the document and elsewhere in this review. See Additional Literature Cited below.). Doing so will accomplish two objectives: (1) make it clear from the outset that we've long since accepted hydrological and ecological connectivity as fundamental tenets and (2) provide critical context for much of the remaining discussion of the specific examples (e.g., l. 2174-2175).</p> <p>1. 1517-518: This sentence is redundant with the following paragraph. I suggest omitted this sentence here altogether, and relying entirely upon the following paragraph to make the point.</p> <p>1. 1697-1698: Water scours channels, not sediments.</p> <p>1. 1698-1701: Add "reducing channel capacity" to the list.</p> <p>1. 1710-1716: Lane (1955) is an excellent way to understand and explain reach-scale flow-sediment dynamics. Because Lane (1955) is often difficult to track down, you might also cite Bull (1991), who republished the findings of Lane (1955).</p> <p>1. 1977-1978: The following two comments relate to nutrient subsidies, which you mention, though not specifically by name, elsewhere in the document (e.g., l. 2174-2175). Drs. Dodds and Wipfli may also mention nutrient subsidies. Therefore, you may choose to consider the following two comments here or elsewhere in a separate paragraph dealing specifically with nutrient subsidies.</p> <p>1. 1977-1978: You might consider adding a paragraph here on seasonal nitrate fluxes in Mediterranean and other similar seasonally arid environments. Such seasonal fluxes have been repeatedly observed and explained as an asynchrony between hydrological and biological processes in annual grasslands in Mediterranean and other similar seasonally arid environments (Tate et al., 1999, Holloway and Dahlgren 2001, Rains et al., 2006). Quoting from the latter: "Upland annual grasses senesce in the dry season. However, microbial activity continues, nitrogen is mineralized, and nitrate accumulates in the upland soils. Annual grasses germinate early in the wet season, but do not develop substantial biomass until the middle- to late-growing season (i.e., March–April). Thus, during the early-season storm events, there is little biological demand for nitrate and it is readily leached from the upland soils into the perched groundwater that ultimately discharges to the vernal pools. Later in the wet season, much of the nitrate in the upland soils has been flushed and the upland annual grasses are flourishing, which produces a large biological demand for the remaining nitrate. Therefore, the amount of nitrate leaching into the perched groundwater and subsequently discharging to the vernal pools decreases."</p> <p>1. 1977-1978: You might consider adding a paragraph here on alder-fixed nitrogen subsidies in wetlands and streams. For example, Shaftel et al. (2010) showed that nitrogen concentrations are correlated with alder cover in salmon-bearing headwater streams on the</p>
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	<p>lower Kenai Peninsula, Alaska. We are now conducting follow up work to determine if all alder patches are created equal in this regard, or if some alder patches are better positioned to provide these subsidies.</p> <p>1. 1987-2001: There is more literature on this issue that you might consider incorporating here. Triska et al. (2007) did a nice study on the transport and transformation of nitrogen as it moved from a hillslope to a headwater riparian wetland and into and down the headwater stream, with the latter being pertinent in this case. Also, Hill and Lymburner (1998) and Hill et al. (1998) did nice studies on nitrogen transformations in hyporheic zones, showing that even short, shallow, and fast flowpaths through the hyporheic zone are sufficient to transform a large amount of the available nitrogen. These studies are all nice compliments to Alexander et al. (2000), which is already described in the document.</p> <p>1.2035-2047: I've always thought of spiraling as a form of short- and long-term storage. Nutrients are essential, yet are always in motion toward the receiving water bodies (e.g., the ocean). Nutrient spiraling is a way by which those nutrients are temporarily stored, perhaps for a short time (e.g., algae), or perhaps for a long-time (e.g., trees), before being released again to downstream ecosystems. This is similar to the roles played by woody debris and floodplains in the short- and long-term storage of sediments.</p> <p>1. 2398-2407: You make a good argument, but you might consider adding the importance of upstream migration. I don't know much about this, but I'm led to believe that invertebrates tend to fly upstream after emergence, all the better to recolonize upstream habitats that tend toward depopulation due to drift. I don't know if this actually true—though it seems that it must be true—or of there is any literature on this if it is true—though I do recall being told that there is literature on this by someone knowledgeable.</p> <p>1. 2486-2487: You might consider adding a paragraph here on the importance of anadromous fish in transporting nutrients, especially marine-derived nutrients, to headwater streams and associated riparian habitats. There is a good review of this in Nadeau and Rains (2007).</p> <p>1. 2486-2487: You might also consider adding a paragraph here on barriers and the effects of barriers. Dynesius and Nilsson (1994) showed that 77% of the total water discharge of the 139 largest river systems in North America north of Mexico, Europe, and the former Soviet Union are fragmented by dams and/or significant water abstraction. Stanford et al. (1988), Ward and Stanford (1995), and Stanford and Ward (2001) talked about this in terms of the natural flow of mass, energy, and organisms, terming the overall effect the Serial Discontinuity Concept. And Fleckenstein et al. (2004) provided a good example of this, by showing that groundwater pumping causes a regional groundwater drawdown, which causes enhanced groundwater recharge through the streambed of the Cosumnes River, which causes the cessation of flow in Cosumnes River in the early fall, which creates a barrier to a fall-run Chinook salmon population.</p>
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<b>Richardson</b>	Yes, the conclusions are consistent with the evidence presented in the scientific, peer-reviewed literature.
<b>Snodgrass</b>	Yes, the scientific evidence clearly indicates a significant influence of physical and biological processes in streams having a large influence on downstream rivers. Streams provide significant amounts of materials (including nutrients, pollutants, sediments, and water) and organisms and control their temporal dynamics and rates of delivery to river systems.
<b>van der Valk</b>	Yes. Although I am not a hydrologist or stream ecologist, this is clearly demonstrated in the literature cited.
<b>Wipfli</b>	Yes, to the best of my knowledge, the conclusions are fully supported by the evidence in the scientific literature. There is strong evidence in the scientific literature that headwaters are physically, biologically, and chemically connected to, and influence, downstream waters and associated biota. The evidence reported and cited in this review is presented accurately, thoroughly, and clearly.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

Reviewer	Comments									
Cooper	See comment 1a) above.									
Crumpton	See comment 1a) above.									
Cummins	<p>By and large the report does include the most relevant peer reviewed literature to address the question. However I have the following comments and recommendations.</p> <table><tr><th><u>Page</u></th><th><u>Line</u></th><th><u>Comment</u></th></tr><tr><td>2</td><td>32</td><td>... spiraling... Unlike standing waters where nutrient cycles are closed loops, the unidirectional flow of streams creates open cycles in which release of a nutrient is displaced from its uptake site. The open nature of the cycles needs to be made clear at the outset. (Also, 8, 184; 8, 190; and the entire section 9, 191-206 should include the concept that the cycles are open.)</td></tr><tr><td>11</td><td>253-60</td><td>A major feature of dams is to reverse the seasonal hydrology of streams and rivers on which they are constructed. The purpose of most dams is to truncate peak flows in the normal season of high runoff (storage for dry season release and use) and to increase flows during these normal low flow seasons. This reversal of normal hydrological patterns has immense implications for life cycles of lotic organisms. This point should be made here or elsewhere.</td></tr></table>	<u>Page</u>	<u>Line</u>	<u>Comment</u>	2	32	... spiraling... Unlike standing waters where nutrient cycles are closed loops, the unidirectional flow of streams creates open cycles in which release of a nutrient is displaced from its uptake site. The open nature of the cycles needs to be made clear at the outset. (Also, 8, 184; 8, 190; and the entire section 9, 191-206 should include the concept that the cycles are open.)	11	253-60	A major feature of dams is to reverse the seasonal hydrology of streams and rivers on which they are constructed. The purpose of most dams is to truncate peak flows in the normal season of high runoff (storage for dry season release and use) and to increase flows during these normal low flow seasons. This reversal of normal hydrological patterns has immense implications for life cycles of lotic organisms. This point should be made here or elsewhere.
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	15 342-44	<p>Furthermore... isolated. In fact, some ecologists have suggested using airshed, watershed, and ground-watershed to categorize all the approximately definable inputs and cycles with in a region.</p>
	23 509-10	<p>Headwater streams are first- and second-order streams... I feel strongly that alternatives to this statement should be acknowledged. For example, the River Continuum Concept (Vannote et al., 1980, cited 4, 708 times so far) groups first-to third-order streams as those headwater streams in which riparian vegetation dominates the in-stream biology. Most orders one to three have canopy closure sufficient to <i>strongly influence</i> in-stream primary production (designated as P/R &lt;1) and the input of plant litter that is the dominant energy base of stream ecosystem function in most headwater streams.</p> <p>Here, and elsewhere, the point should be driven home that stream order is a geomorphic concept and probably never should be inferred from blue lines on a map, which can represent anything from first-order to fourth-order depending on map scale. In addition, the stream class system of categorizing streams by fish-bearing condition (e.g., California Forest Practices Rules, Section 936.4) should be laid to rest. This is not a geomorphic defensible classification and should be permanently discouraged. [“Class I watercourses are defined as fish always or seasonally present onsite, including habitat to sustain fish migration and spawning. Class II waters are defined as 1) fish always or seasonally present off-site within 1000 feet downstream and/or 2) aquatic habitat for non-fish aquatic species. Class III watercourses do not have aquatic life present” (This is impossible at all seasons and in all years – e.g., aquatic Diptera, appear within days of flooding of forest access roads) “and are capable of sediment transport to Class I and II waters under normal high water flow conditions. (Cummins, K. W. and M. A. Wilzbach. 2005. The inadequacy of the fish-bearing criterion for stream management. Aquatic Sciences. <i>On line</i>; <a href="http://www.birkhauser.ch">http://www.birkhauser.ch</a>, pp 1-6).</p>
	24 531	<p>...symmetry ratio... another way is link number, which sums the total number of first-order tributaries entering a watershed of a given order. Fig. 3-1 shows no first-order tributaries entering directly into the third-order mainstem which would be quite unusual. Link number is a useful measurer for stream ecologists working at the watershed scale because the first-order tributaries are those in which the riparian influence on in-stream biological community composition and productivity is maximized.</p>
	26 559	<p>Fig. 3-3. The diagram’s horizontal bars give no indication about the massive controversy about the width of riparian areas. This point is the major element of all forest practice rules, including the sentinel Northwest Forest Plan that defines the width in terms of tree height in the riparian area. The point that needs to be acknowledged (driven home), is that stream ecologists, fisheries managers, and forestry managers all have different concepts (or biases) about the definition of the width. For</p>

		<p>example, stream ecologists may focus on the width necessary to provide the width that supplies plant litter that constitutes the primary energy source of headwater stream ecosystems, fisheries managers are concerned with the width necessary to insure the input of large wood which is the mainstay of fish habitat in streams and rivers in general, and forestry managers are concerned with how much width will be excluded from harvest by almost all forest practices rules. So, for scientific, Endangered Species Act, and economic reasons defining the width or the criteria for defining the width of the riparian zone is far from a trivial matter. At least replace the end bars on the riparian widths in Fig. 3-3 with a dashed line at the ends. The figure caption should explain that the dash lines indicate that the boundary of the riparian zone depends upon the function being considered (e.g., Gregory et al., 1991).</p>
51	1000	<p>Figure 3-14). Also, dissolved organic matter (DOM) forms complexes with divalent cations, primarily Ca, converting DOM to fine particulate organic matter (FPOM, particle size &lt; 1mm) and is taken up directly by benthic bacteria. This significantly delays the export of organic matter down river. DOM almost universally accounts for 50% of all the organic matter in transport in all order streams (Vannote et al., 1980 and the Minshall et al., River Continuum publications). This retention of FPOM, rather than loss as DOM, has major consequences for stream and river invertebrates and is likely a major factor in the productivity of hard water (calcium rich) streams.</p>
80	1484	<p>Swanson et al. (1987) suggest that short recurrence intervals involve flows too small to cause significant changes in stream channel geomorphology, and very long recurrence intervals cause very major alterations in channel form, but the intermediate recurrence intervals are the events that have the major effects in shaping the current condition of most channels.[Swanson, F. J., L. E. Benda, S. H. Duncan, G. E. Grant, W. E. Megahan, L. M. Reid, and R. R. Zimmer. 1987. Mass failures and other processes of sediment production in Pacific Northwest forest landscapes. Pp. 91-138 <i>in</i>: Salo, E. O. and T. W. Cundy. (eds.). Streamside management: forestry and fisheries interactions. Institute of Forest Resources, Univ. Washington, Seattle. (If the NRC publication is cited, this one should be eligible as well; it was reviewed by outsiders.)]</p>
108	2106	<p>Cite Cushing et al. (eds.). 2006. This 817 page volume includes chapters by worldwide authors on streams and rivers of North America, Central and south America, Europe, Africa, Asia, Australia and New Zealand, and Oceania. The editors charged the authors with using data from streams and rivers in their respective regions and comparing it with the River Continuum Concept (Vannote et al., 1980). The comparisons are about linkages (connectivity) between headwater streams and large rivers on a world wide scale. The introduction by the editors presents an overview of stream ecosystems. The River Continuum Conceptual Model (Vannote et al., 1980) is reproduced in the Introduction. This is the model that relates</p>

		stream/river ecological structure and function to the position along the downstream trajectory. (Cushing, C. E., K. W. Cummins, and G. W. Minshall. 2006. River and stream ecosystems of the world. Univ. California Press, Berkeley 817 p.)
110	2145	...108 m for whole leaves... This compares to the 100 m in Cummins et al. (1989) and not to the 1000 m cited in this report.
112	2197	...snow melt. Approximately 50% of transported carbon was DOC in all streams (orders 1-8) covered in the River Continuum studies (Vannote et al., 1980, Minshall et al., 1983, 1992).
112	2206	...river network. An important point here is that anaerobic storage of CPOM, e.g., leaf litter, greatly delays breakdown of CPOM to FPOM in the absence of hyphomycete fungi and shredders, both of which are obligate aerobes (Cummins et al., 1980. [Cummins, K.W., G.L. Spengler, G.M. Ward, R.M. Speaker, R.W. Ovink, DC Mahan, and R.L. Mattingly. 1980. Processing of confined and naturally entrained leaf litter in a woodland stream ecosystem. Limnol. Oceanogr. 25:952-957.]
120	2382	Wilzbach and Cummins (1989) demonstrated a higher % mortality among drifting individuals than their benthic counterparts. This raises the possibility that a significant amount of invertebrate stream drift is destined to have no impact on downstream colonization of invertebrates, with the primary effect being the contribution being to the downstream detrital suspended load. (Wilzbach, M. A. and K. W. Cummins. 1989. An assessment of short-term depletion of stream macrobenthos by drift. Hydrobiologia 185: 29-39.
146	2970	...gatherers, the dominant group... the term is defined, but as in the case of shredders (which was not defined or referenced when used) no citation is given. There are a great many that could be used, e.g., Cummins 1974, Cummins and Klug 1979. [Cummins, K.W. 1974. Structure and function of stream ecosystems. BioScience 24: 631-641; Cummins, K.W. and M.J. Klug. 1979. Feeding ecology of stream invertebrates. Ann. Rev. Ecol. Syst. 10:147-172; the designations are also part of the River Continuum Concept.]
148	3002	...reaches 500 and 1,000 m upstream. Distance traveled by the majority of introduced leaf litter in a forested second-order stream by reported to be about 100 m by Cummins et al. (1989). [Travel distance of leaf litter was reported from the time the litter is wetted. Senescent Ginkgo leaves were used in these experiments; they are bright yellow and remain so for several weeks because they are very resistant to biological processing. Also, the leaf shape is unlike any of the native riparian tree species in eastern headwater streams.]
		Attached is a figure that might be of interest to some people at the meeting. I make no suggestion whatsoever that this Figure should be any part of the report. It is merely a “snap shot” offered in support of the argument that I did make in the report about including more

detail on one of the sentinel features of connectivity between riparian vegetation and structure, function and productivity of invertebrate populations in headwater streams (which I would define as first- to third-order). The photograph is not unique; this sort of picture could be taken of leaf litter from any stream in the world during any season when riparian plant litter is available in streams (including intermittent channels). I have such pictures from streams in southern and northern California, Oregon, New Mexico, Yellowstone Park (Wyoming and Montana), Idaho, Michigan, Pennsylvania, Maryland, Florida, Sweden, Denmark, Italy, Australia, New Zealand, Brazil, and Guinea West Africa.



Fig. A. Conditioned red alder leaf eaten by caddisfly (Trichoptera) larvae. Note: better conditioned (higher aquatic hyphomycete fungal biomass) soft tissues eaten in preference to the poorly conditioned midrib and major veins which are high in lignin. (Cummins et al., 1989).

Just for background information. A companion to the comment at page 146, Line 2970, Response to Technical Charge Question 1.

So, as I argued in one of my comments in Response to Charge question 1, this world wide and highly predictable connection between riparian vegetation and in-stream biology is worthy of more than the undefined use of the term “shredders” which occurs at a single place in the report. There are over 1,000 references in the literature that address this example of connectivity.

**Dodds**

This report is well referenced. There are so many references on this subject, that it would be impossible to include them all. The document however, does cite plenty of references that clearly illustrate the main points of the report.

<b>La Baugh</b>	A useful reference regarding the interaction of streams and groundwater is absent from the references – Jones, J.B., and Mulholland, P.J., eds. 2000. <u>Streams and Ground Waters</u> , Academic Press, 425 p.
<b>Rains</b>	See comment 1a) above.
<b>Richardson</b>	<p>The authors provide a comprehensive suite of references to support their summary and conclusions. These references are the most relevant, and other papers that come to mind would not further enhance the understanding of the topic. One that deals with the punctuated delivery of large wood to channels and its storage and lag processes is by Swanson et al. (1998).</p> <p>Swanson, F.J. et al. 1998. Flood disturbance in a forested mountain landscape - Interactions of land use and floods. <i>BioScience</i> 48:681-689.</p>
<b>Snodgrass</b>	<p>Although the report is focused on influences that move from upstream to downstream (as is clearly stated in the report), some degree of isolation of headwater streams is important for the biological integrity of these habitats. For example, some species of stream-side salamanders are headwater specialist, which are only found in large numbers in headwater streams (Snodgrass et al., 2007; Peterman et al., 2009). Headwater specialists often have adaptations that allow them to cope with desiccating conditions that limited the development of predator populations (Meyer et al., 2007). Many insects as well as other invertebrate taxa are also endemic to headwater streams (e.g., Dieterich and Anderson, 2000; Fend and Brinkhurst, 2000; Fend and Gustafson, 2001). Therefore, protection of the isolated nature of headwater streams is also an important component of protecting the biodiversity associated with our nation's waters. The authors do acknowledge these ideas (see lines 906-907; 1020-1022), but I feel they are also important for managers and policy maker to appreciate. If the main focus of the report is the emphasis of effects on downstream waters, then more detailed treatment of the influence of connectivity on upstream headwaters and wetlands may not be warranted.</p> <p>Although not crucial to demonstrating the influence of headwater streams for downstream rivers, in the sake of being complete it is probably worth noting the role of beavers in the functioning and influence of headwaters on downstream rivers. Beavers can dam extensive lengths of moderate to low gradient headwater streams (e.g., Snodgrass 1997), greatly altering their hydrology and geomorphology (Pollock et al., 2003; Butler and Malanson, 2005) and provide habitat for numerous organisms (e.g., Snodgrass and Meffe 1996; Stevens et al., 2006). These hydrological and geomorphological changes have large impacts on ecosystem function (Naiman et al., 1996) including greatly increased rates of denitrification (Naiman et al., 1994). Additionally, beaver ponds can be areas of high rates of mercury methylation (Roy et al., 2009). These points relate to the idea of headwater streams being places of lag and transformation. This material should be added as the wetlands that beavers form would fall into the floodplain/riparian category of wetlands.</p> <p>When the authors discuss mapping issues for headwater streams (lines 1519-1530) they should include the Brooks and Calhoun (2011) reference; they might even include some numbers from this publication. Specifically, Brooks and Calhoun (2011) estimate that 21%</p>

	<p>of 400.3 km of stream did not show up as blue lines on 1:25,000 scale USGS topographic maps. There is also the issue of channels that were formed under past land use scenarios that currently do not ever hold flowing water. Although the definition of “stream” includes flowing water (lines 503-504) later the authors suggest that headwater stream originate at where “runoff is sufficiently concentrated to erode a definable channel” (line 518). Some clarification should be included to make it clear that there are two components to a stream: flow at some time during the year and the formation of a channel.</p> <p>On lines 3399 through 3413 the authors summarize the effects of altered flow regimes on invasiveness of native communities. Meffe (1984) should probably be cited here as this is one of the original, if not the original, documentation of the influence of natural flow regimes on co-existence of native and introduced fish species. Additionally, the bullet on line 3434 should include the prevention and/or mitigation of the effects of invasion by introduced species. Again, this is a place to integrate the balance between lag and source and how their alteration can impact downstream rivers.</p>
<b>van der Valk</b>	<p>Again, I am not a hydrologist, this review, however, cites a large number of relevant references to document the connectivity of streams to rivers. I doubt that any additional references would in any way alter the conclusions drawn.</p>
<b>Wipfli</b>	<p>Yes, to the best of my knowledge, the report includes a broad, relevant literature on the connections between headwaters and downstream freshwater ecosystems. However, I did not see literature discussed and cited that addresses the linkages between headwaters and estuaries and oceans, even though that point is stated in the first paragraph of “Background” section of “Technical Charge to External Peer Reviews” document. Should this be included?</p> <p>Five additional references from my headwaters work on biological linkages that may be helpful are listed below. The latter four deal with management effects on headwater streams.</p> <p>Wipfli, M.S., and C.V. Baxter. 2010. Linking ecosystems, food webs, and fish production: Subsidies in salmonid watersheds. <i>Fisheries</i> 35(8): 373-387. <i>This paper takes a broader look at watersheds, putting into context the biological connections between headwaters, river networks, riparian habitats, and the ocean.</i></p> <p>Binckley, C., M.S. Wipfli, R.B. Medhurst, K. Polivka, P. Hessburg, B. Salter, and J.Y. Kill. 2010. Ecoregion and land-use influence invertebrate and detritus transport from headwater streams. <i>Freshwater Biology</i> 55: 1205-1218. <i>This paper shows how past timber harvesting affects invertebrate flow from headwaters to downstream habitats.</i></p> <p>Medhurst, R.B., M.S. Wipfli, K. Polivka, C. Binckley, P. Hessburg, and B. Salter. 2010. Headwater streams and forest management: Does ecoregional context influence logging effects on benthic communities? <i>Hydrobiologia</i> 641: 71-83. <i>Addresses past timber harvest effects on headwater stream invertebrate communities.</i></p> <p>Wipfli, M.S. and J. Musslewhite. 2004. Density of red alder (<i>Alnus rubra</i>) in headwaters influences invertebrate and organic matter subsidies to downstream fish habitats in Alaska. <i>Hydrobiologia</i>. 520: 153-163. <i>This paper showed that headwater streams</i></p>

	<p><i>also supply terrestrial invertebrates to downstream waters, in addition to aquatic invertebrates, and illustrated how riparian management affects biological connections between riparian areas, headwater streams, and downstream waters.</i></p> <p>Piccolo, J.J., and M.S. Wipfli. 2002. Does red alder (<i>Alnus rubra</i>) along headwater streams increase the export of invertebrates and detritus from headwaters to fish-bearing habitats in southeastern Alaska? <i>Canadian Journal of Fisheries and Aquatic Sciences</i>. 59: 503-513. <i>This paper looks at how riparian regrowth following timber harvest in Alaska affects transport of aquatic invertebrates to downstream waters.</i></p> <p>Another paper from research we conducted on headwater streams looking at the role of wildfire in affecting linkages between headwater streams and downstream waters, via the flow of invertebrates downstream:</p> <p>Mellon, C.D., M.S. Wipfli, and J.L. Li. 2008. Effects of forest fire on headwater stream macroinvertebrate communities in eastern Washington, USA. <i>Freshwater Biology</i> 53: 2331–2343.</p>
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**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Reviewer	Comments
Cooper	See comment 1a) above.
Crumpton	See comment 1a) above.
Cummins	The Literature that was cited was summarized correctly.
Dodds	<p>Yes, the literature was reviewed and cited correctly. One minor addition could be that there is one reference that is cited, Dodds and Oakes 2006, which indicates that intermittent streams are connected chemically to larger streams and rivers even during times of the year when the streams are not flowing. This point is not mentioned but is very important to the issue of connectivity.</p> <p>I found the illustrative materials in this section quite useful and well done. However, I would like to see the figures such as 3-6 include diagrams of losing stream reaches as well, although figure 3-13 helps. Also a figure with a longitudinal cross section indicating hyporheic flow, and how such flow can connect isolated pools during dry periods could also be useful. Finally, Table 3-1 is a bit confusing as it looks like everything flows into everything else through the river. I would just lose the multiple italicized words in the first column that say “River”, or space out the individual rows further to make it clear that each row is not linking to the next. I think figure 3-14 is somewhat misleading as it ignores cycling through inorganic forms.</p> <p>Line 1031, these streams flow during and immediately following precipitation.</p>

	<p>A clearer discussion of when increased connectivity can be bad (e.g., introduced species) might be useful. The information was in the document, but buried. (e.g., at line 1408).</p> <p>Line 1772, confluences are not “much like dams”, they can change longitudinal patterns, but much less severely and in very different ways from dams.</p> <p>Line 1793. In the Flint Hills of Kansas, wood does not accumulate in small streams, and such streams are an important source of large wood to downstream rivers. This wood is very important habitat as well as a geomorphologic force in rivers. This statement might need to be qualified a bit.</p> <p>Line 2495, might want to discuss the Falke and Gido 2006 (in references) work here on reservoirs disconnecting small streams from each other.</p> <p>Line 2560. This could be stated more strongly. The evidence unequivocally demonstrates connectivity between streams and downstream rivers.</p> <p>Line 2589. Work of Alexander et al. (2000) and Mulholland et al. (2008), Woolheim et al. (2008) both explicitly examine movement of materials along river network. This reference is also important Helton, A.M., Poole, G.C., Meyer, J.L., Wollheim, W.M., Peterson, B.J., Mulholland, P.J., Bernhardt, E.S., Stanford, J.A., Arango, C. &amp; Ashkenas, L.R. (2010) Thinking outside the channel: modeling nitrogen cycling in networked river ecosystems. <i>Frontiers in Ecology and the Environment</i>, 9, 229-238.</p> <p>Line 2718. The fact that nutrients are elevated in most ecoregions, and these are generally related to non-point source land use characteristics, is highly indicative of stream connection. Dodds, W.K. &amp; Oakes, R.M. (2004) A technique for establishing reference nutrient concentrations across watersheds affected by humans. <i>Limnology and Oceanography Methods</i>, 2, 333-341.</p> <p>Line 2750, these are still net heterotrophic, so they are derived to a lesser degree than forested areas.</p> <p>Line 3059, this pattern was also probably driven by bass in the impoundments.</p> <p>Figure 4-9 the title is wrong.</p>
<b>La Baugh</b>	<ul style="list-style-type: none"> <li>• <b>Page 42, line 828; page 175, line 3579; page 307, line 6921</b> – <u>The name Meybloom in the citation is incorrect. Correct name for this citation is Meyboom.</u></li> <li>• I am not familiar with all of the literature cited in the document regarding the relation of streams to their connection with and influence on downstream rivers, therefore I am not able to judge whether or not all of the cited literature was summarized correctly.</li> </ul>
<b>Rains</b>	See comment 1a) above.
<b>Richardson</b>	The review provides a solid assessment of the literature and covers the evidence for connections. Yes, the conclusions are supported and appropriate literature is compiled. The authors have been careful throughout to point out any uncertainties in the conclusions that can be drawn from the available literature. The only limitation to the assertion that all

	streams are connected to rivers might be in the case of coastal streams not contributing to a nexus with a navigable-in-fact river, but these are still connected to streams (or estuaries) downstream.
<b>Snodgrass</b>	In general, the literature interpretation is correct and the literature cited extensive. I have only a few minor comments here. On lines 2412 through 2414 the authors suggest that most fishes utilizing headwaters can also be found further downstream and cite Horitz (1978). This may be true for more species poor assemblages, but in more species rich areas it is common to find species of fish confined to headwater streams. See discussion above for references. This change should be made in the final document.
<b>van der Valk</b>	I am not an expert on hydrology, but I did not find any obvious problems with literature citations or with the interpretations of the literature.
<b>Wipfli</b>	<p>Yes, the literature in this report was cited and summarized accurately. The authors provided a very clear and thorough illustration of the demonstrated linkages that connect headwaters to downstream waterways.</p> <p>A few points that might help:</p> <p>Line 1494 – “and associated biota” at the end of the sentence?</p> <p>Lines 1698, 1709, 1844 – Several places in the text (these two as examples) could benefit with a relevant citation.</p> <p>Lines 1793-4 and 1804-6 seem to be in conflict with each other.</p> <p>Line 2160 – space before 100.</p> <p>Line 2375 (whole section) – this would be a good place to discuss the role of terrestrial invertebrates that enter headwaters, and in turn get transported downstream from headwaters (Wipfli and Musslewhite 2004). Not sure if the authors would like to have this concept in the report, but it also ties in human impacts into the story.</p>

2. This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.

a) Are these conclusions supported by the scientific evidence?

Reviewer	Comments
Cooper	The report provides evidence of these connections, but what is missing is some idea of how often and how long these connections must occur each year. I would also like to see a better review of the types of channels and wetlands that occur in the U.S. and which we have sufficient evidence for these connections, and which we don't. This could be presented in a table.
Crumpton	<p>The conclusion that wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network is well supported by the scientific evidence (with the possible exception of wetlands in riparian areas and floodplains of certain permanently losing streams that are never connected to downstream waters- these systems would be rare). The report illustrates this through literature documenting the unidirectional and bidirectional transfer of water and materials and transport and migration of organisms.</p> <p>The conclusion that wetlands in riparian areas and floodplains of streams and rivers exert a strong influence on the character and function of downstream waters is well supported by the scientific evidence – <u>at least for the systems collectively, and that qualification should be included in the conclusion.</u></p> <p>The report provides sufficient coverage of the relevant peer-reviewed literature on physical, chemical connections of wetlands in riparian areas and floodplains to the stream networks. The literature was cited and summarized correctly. The report recognizes the uncertainty in quantifying exchanges between stream/ river channels and their riparian areas/floodplains and provides sufficient documentation of the transfers without extending the analyses beyond what can be reasonably concluded.</p>
Cummins	The conclusions are supported by the scientific evidence.
Dodds	Yes, these conclusions are supported.
La Baugh	<p>The general synthesis of the cited literature provided in the report appears to support conclusion 2. Part of the text pertaining to the relation of open water and riparian wetlands to streams and rivers would benefit from clarification, as noted below.</p> <ul style="list-style-type: none"> <li>• <b>Page 2, lines 38 and 39; page 10, line 225</b> – <u>The phrase "...storage of local groundwater sources of baseflow in rivers," could benefit from clarification. Was the intent of the text that riparian and floodplain wetlands are areas where groundwater flows to the wetlands rather than the adjacent river, thereby intercepting groundwater that otherwise would contribute to baseflow?</u></li> </ul>

<p><b>Rains</b></p>	<p><b>SUMMARY</b></p> <p>The conclusions are supported by the scientific evidence provided. This is still a relatively easy task for the authors, because hydrological and ecological connectivity are fundamental tenets for these systems. However, I do have comments regarding some flaws and/or inadequacies in the scientific evidence provided as justification. (See, also, the detailed comments related to the conceptual framework in the section titled “Additional Reviewer Comments” below.)</p> <p><b>DETAILED COMMENTS</b></p> <p>General Comment: The classification scheme used in this document is unusual. I understand why you might want to separate this into channels, wetlands on floodplains, and wetlands not on floodplains, given the regulatory environment. However, this is not a common way to classify wetlands, which makes the document a bit hard to follow. I think that you can leave this general separation in place, but you might then explain what kinds of wetlands might be included, using an HGM classification scheme. In this way, you can explain that this chapter is dealing with all kinds of wetlands—riverine as well as flat, depressional, slope, lacustrine, and estuarine—as long as they are subject to regular or episodic flooding and therefore connection to streams.</p> <p>1. 3524-3556: This entire section would be greatly strengthened if you would include a review of some of the papers that show that hydrological and ecological connectivity are central tenets of floodplain hydrology and ecology. Some examples might include the Flood Pulse Concept (Junk et al., 1989, Tockner et al., 2000) and the extension of the Serial Discontinuity Concept to floodplains (Ward and Stanford 1995). Doing so will accomplish two objectives: (1) make it clear from the outset that we’ve long since accepted hydrological and ecological connectivity as fundamental tenets and (2) provide critical context for much of the remaining discussion of the specific examples.</p> <p>1. 3574-3575: You might also consider adding a paragraph here on the role that bank storage plays in supporting baseflow, especially immediately following high flows (Whiting and Pomeroy 1997, Hammersmark et al., 2008).</p> <p>1. 3584-3585: Here and in a few other locations, you use the word “filter” to describe sediment removal from flowing water by riparian and floodplain wetlands. However, it isn’t a filtering effect, it’s a hydraulic effect, as water slows, loses strength (e.g., specific stream power), and deposits sediments, usually in order of mass (Meyer et al., 1995, Dabney et al., 1995). You know this to be true, because you go on to say as much later (e.g., l. 3601-3602). This is a little issue; but you’ll forgive me because it’s a pet peeve of mine.</p> <p>1. 3601: Riparian areas are both sources and sinks for sediments. Riparian areas provide both short- and long-term storage locations for sediments, and can be sediment neutral, sediment sinks, or sediment sources depending upon whether the stream has reached its base profile—in which case sediment storage and mobilization balance; accommodation space has been created—in which case, sediments can be stored; or accommodation space has been destroyed—in which case, sediments can be mobilized (Quirk 1996).</p>
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	<p>1. 3609-3618: This paragraph seems out of place, in that it doesn't seem to connect to the surrounding discussion of connectivity, but it will fit much better if you broaden the previous paragraph as suggested in my comment titled "1. 3601".</p> <p>1. 3644-3646: Groundwater does not always move through the alluvium and/or equilibrate with the temperature of alluvium. Some groundwater that discharges to riparian environments flows along regional groundwater flowpaths, and is therefore more likely to have the temperature of the volumetric weighted average of the recharge water (Rains and Mount 2002, Kish et al., 2010).</p> <p>1. 3695-3697: This paper, and a few others, has created a lot of headaches in recent years, because of sentences just like this, which imply that evapotranspiration causes water levels to rise. The paper, in my opinion, is a bit flawed, in that it misrepresents the net effect of evapotranspiration and makes a claim wholly unsubstantiated by the data. Let me deal with these issues on at a time. First, evapotranspiration causes a net decline in water levels, which will tend to move water out of the carbon-rich soils. Hydraulic lift does occur, but that only partially offsets the initial drawdown. Imagine a point just below the water table but in the carbon-rich soils. Before evapotranspiration, that point is saturated, so the pressure potential is positive. After evapotranspiration, the water table declines to below that point, so the point is unsaturated, so the pressure potential is negative. At this point, water can flow uphill, down the pressure gradient, from the water table up toward the point. (This, in fact, is the source of the well-known capillary fringe.) The point may not be saturated—in fact, in most alluvial deposits, the point will not be saturated—though it likely will be moister than in the absence of the hydraulic lift. Still, the net effect, for this point, is that it went from saturated to unsaturated, which means that less water, not more water, is in the carbon-rich soils. Second, this means that less, not more, N transformations are likely to occur. More importantly, Kellogg et al. (2008) wasn't about N transformations at all—this was just a purely speculative paragraph based upon no data that, quite frankly, the editors and reviewers at JAWRA should have asked to be removed.</p> <p>1. 3702-3705: What do you mean by "redoxing agents"?</p> <p>1. 3708-3734: This entire section is poorly referenced. This is nitrogen in riparian and floodplain wetlands, for which there are many studies, and yet only one study is referenced. Granted, the paper is good, and well referenced itself, but it seems like you, too, could bolster your argument with additional references, such as the roles played by riparian wetlands in reducing nitrogen loads in agricultural runoff (Peterjohn and Correll 1984), the roles played by hyporheic flows, including those at the channel-floodplain interface, in reducing nitrogen in stream waters (Dahm et al., 1998, Hill and Lymburner 1998, Hill et al., 1998), and the role that linked hillslopes-headwater wetlands-headwater streams play in reducing nitrogen loads as water flows from hillslopes to river networks (Triska et al., 2007).</p> <p>1. 3835-3836: Add Tockner et al. (2000) to the references here. Junk et al. (1989) developed the flood-pulse concept for tropical rivers; Tockner et al. (2000) extended the flood-pulse concept to temperate rivers.</p>
<b>Richardson</b>	This provides a very good summary of the literature and the conclusions are supported.

<b>Snodgrass</b>	On lines 233 and 234 the authors suggest that riparian buffer zones are one of the most effective tools for mitigating non-point source pollutants. This is true for non-point source pollutants such as nutrients and sediments that might enter riparian areas in groundwater and runoff, but may not be true for other pollutants such as road salts and organic compounds. I think we need to be careful of promoting riparian areas as a cure for all ills while still clearly indicating where they are useful. Given the length of the document and its focus on downstream effects the author may not need to address this comment in their final edits.
<b>van der Valk</b>	Yes. The multiple connections (surface water, groundwater, biological) between rivers and floodplain wetlands were well documented.
<b>Wipfli</b>	Yes, to the best of my knowledge, the conclusions are fully supported by the evidence in the scientific literature. There is strong evidence in the scientific literature that riparian area wetlands and other waters are physically, biologically, and chemically connected to, and influence, the river network. The evidence reported and cited in this review is presented accurately, thoroughly, and clearly.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

Reviewer	Comments									
Cooper	See comment 2a) above.									
Crumpton	See comment 2a) above.									
Cummins	<p>By and large the report does include the most relevant peer reviewed literature to address the question. However I have the following comments and recommendations.</p> <table><tr><th><u>Page</u></th><th><u>Line</u></th><th><u>Comment</u></th></tr><tr><td>7</td><td>161</td><td>...rivers. At some point, perhaps here, cases in which headwater streams are not the initial source of river networks should be flagged. For example, the Yellowstone River (one of the longest and largest un-dammed rivers in North America) originates from Yellowstone Lake. The lake itself is fed by numerous small tributaries which are not episodic connections. This natural configuration conforms to essentially all human-constructed reservoirs in North America.</td></tr><tr><td>175</td><td>3573</td><td>...outside edges of riparian areas... See comment 26, 559 (Fig. 3-3). This implies the width of riparian areas has been defined (as argued at 26, 559, there is little agreement about this, because the width is dependent upon the function being considered or the management objectives dependent upon the width as define by regulations. For example, foresters interested in timber harvest will argue for the smallest width possible while fisheries managers will argue for a width sufficient to provide recruitment of LWD.</td></tr></table>	<u>Page</u>	<u>Line</u>	<u>Comment</u>	7	161	...rivers. At some point, perhaps here, cases in which headwater streams are not the initial source of river networks should be flagged. For example, the Yellowstone River (one of the longest and largest un-dammed rivers in North America) originates from Yellowstone Lake. The lake itself is fed by numerous small tributaries which are not episodic connections. This natural configuration conforms to essentially all human-constructed reservoirs in North America.	175	3573	...outside edges of riparian areas... See comment 26, 559 (Fig. 3-3). This implies the width of riparian areas has been defined (as argued at 26, 559, there is little agreement about this, because the width is dependent upon the function being considered or the management objectives dependent upon the width as define by regulations. For example, foresters interested in timber harvest will argue for the smallest width possible while fisheries managers will argue for a width sufficient to provide recruitment of LWD.
<u>Page</u>	<u>Line</u>	<u>Comment</u>								
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	<p>177 3615 ...such as black willow... As discussed at 74, 1363, the physical bank stabilization characteristics of black willow need to be balanced against the potential disruptive effects on the aquatic ecosystem involved, e.g., stream or wetland. A very important point about connectivity between the riparian zone and the adjacent aquatic system and, therefore, the connectivity downstream is that the plant species composition of the riparian has a very significant impact on the timing and nature of these downstream contributions. (e.g., Cummins et al., 1989).</p> <p>184 3771-72 Allochthonous inputs...food webs...(reviewed in Tank et al. 2010). This could use some other review references (e.g., Cummins 1974, Vannote et al. 1980, Cummins 2002) and many others). [Cummins, K. W. 2002. Riparian-stream linkage paradigm. <i>Verh. Verein. Limnol.</i> 28: 49-58.]</p> <p>187 3842-44 Thus, lateral... river systems. Here or elsewhere cite Junk et al., 1989. Most stream ecologists would cite this paper as one of the major additions to the River Continuum Concept.</p> <p>[Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The Flood Pulse Concept in river floodplain systems. Pp 110-127 in: Dodge, D. P. Proceedings of the international large river symposium. <i>Can. Spec. Publ. Fish. Aquat. Sci.</i> 106.]</p> <p>189 3881-82 See also notes about black willow (74, 1363; 177, 3771-72.</p>
<b>Dodds</b>	Yes, there is much current and relevant literature cited.
<b>La Baugh</b>	No response as this is not a focus of my area of expertise.
<b>Rains</b>	See comment 2a) above.
<b>Richardson</b>	The literature covered is excellent.
<b>Snodgrass</b>	To the best of my knowledge in this area the report does include the most relevant literature. However, this is not my area of expertise as I have conducted little work in floodplain systems.
<b>van der Valk</b>	<p>The relevant literature on floodplains is huge and unequivocal about the connectivity of rivers and their floodplains. Although this review does not cite some relevant literature on floodplain development (e.g., J. S. Bridge. 2003. <i>Rivers and Floodplains: Forms, Processes, and Sedimentary Record</i>. Blackwell), it cites the most relevant reviews on connectivity between rivers and floodplains like Amoroso and Bornette (2002). Again, I doubt that the conclusions drawn from the literature reviewed would be affected in any way because some relevant references were not included.</p> <p>Some relevant papers from outside NA that are missing include:</p> <p>Boschilia, S.M., E.F. Oliveira, and S.M. Thomaz. 2008. Do aquatic macrophytes co-occur randomly? An analysis of null models in a tropical floodplain. <i>Oecologia</i> 156: 203-214.</p>

	<p>Henry, C.P., C. Amoros, and N. Roset. 2002. Restoration ecology of riverine wetlands: a 5-year post-operation survey on the Rhone River, France. <i>Ecological Engineering</i> 18: 543-554.</p> <p>Paillex, A., S. Doleddec, E. Castella, and S. Merigoux. 2009. Large river floodplain restoration: predicting species richness and trait responses to the restoration of hydrological connectivity. <i>Journal of Applied Ecology</i> 46: 250-258.</p> <p>Vervuren, P.J.A., C.W.P.M Blom and H. de Kroon. 2003. Extreme flooding events on the Rhine and the survival and distribution of riparian plant species. <i>Journal of Ecology</i> 91: 135-146.</p>
<b>Wipfli</b>	Yes, the report appears to include the most relevant literature that shows how off-channel freshwater habitats are connected to mainstem channels and riverine networks.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

<b>Reviewer</b>	<b>Comments</b>
<b>Cooper</b>	See comment 2a) above.
<b>Crumpton</b>	See comment 2a) above.
<b>Cummins</b>	Literature was cited and summarized correctly. (Except see note at 184, 3771-72.)
<b>Dodds</b>	<p>The only major issue I have with this section is not so clearly separating literature on riparian areas that are not technically wetlands from those that are. I understand that the authors of this document did not want to leave out riparian areas completely because it is clear that ANY riparian area is connected to the stream it abuts. However, there needs to be clearer separation of these. Perhaps a specific section on riparian areas generally, then a second on riparian wetland areas.</p> <p>Table 5-2, not only is considering a stream without riparian influence limiting, it will give incorrect results. Also in this table, water storage needs to be mentioned</p> <p>Line 4496, might also want to include work by David Galat:</p> <ol style="list-style-type: none"> <li>Galat, D.L., Fredrickson, L.H., Humburg, D.D., Bataille, K.J., Bodie, J.R., Dohrenwend, J., Gelwicks, G.T., Havel, J.E., Helmers, D.L., Hooker, J.B., Jones, J.R., Knowlton, M.F., J. Kubisiak, J.M., Mccolpin, A.C., Renken, R.B. &amp; Semlitsch, R.D. (1998) Flooding to restore connectivity of regulated, large-river wetlands. <i>Bioscience</i>, 48, 721-733.</li> <li>Galat, D.L. &amp; Lopkin, R. (2000) Restoring ecological integrity of great rivers: historical hydrographs aid in defining reference conditions for the Missouri River. <i>Hydrobiologia</i>, 422/423, 29-48.</li> </ol>

	<p>c. Galat, D.L. &amp; Zweimüller, I. (2001) Conserving large-river fishes: is the <i>highway</i> analogy an appropriate paradigm? <i>Journal of the North American Benthological Society</i>, 20, 266-279.</p> <p>I am surprised there is not more on the Kissimmee restoration as wetland connectivity was essential to this project. The Dahm, C.N., Cummins, K.W., Valett, H.M. &amp; Coleman, R.L. (1995) An ecosystem view of the restoration of the Kissimmee River. <i>Restoration Ecology</i>, 3, 225-238.</p>
<b>La Baugh</b>	I am not familiar with all of the literature cited in the document regarding the relation of open water and wetlands in riparian areas and floodplains of streams and rivers to their connection with and influence on downstream rivers, therefore I am not able to judge whether or not all of the cited literature was summarized correctly.
<b>Rains</b>	See comment 2a) above.
<b>Richardson</b>	<p>The interpretations of what is known and the limitations of inferences possible from the literature are fine. The authors do a very good job throughout the document of ensuring they point out the uncertainties in demonstrating significant connections. Good examples given to describe the types of wetlands and their connections to navigable rivers.</p> <p>I find the use of the term riparian a little confusing. It would be hard to distinguish functionally or structurally in most cases how a floodplain differed from a riparian area, so to refer to “riparian and floodplain” wetlands seems redundant (see definition of riparian on P.26). This also goes to whether there is such a thing as a non-riparian wetland, as a wetland should generate its own riparian area. Perhaps this should be defined as a non-floodplain wetland.</p>
<b>Snodgrass</b>	To the best of my knowledge in this area the report does correctly interpret and cite the literature. However, this is not my area of expertise as I have conducted little work in floodplain systems.
<b>van der Valk</b>	I am not an expert on riverine hydrology, but I did not find any obvious problems with literature citations or with the interpretations of the literature.
<b>Wipfli</b>	Yes, the literature in this report was cited and summarized thoroughly and correctly.

3. This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.

a) Are these conclusions supported by the scientific evidence?

Reviewer	Comments
Cooper	This is correct. Documented evidence of hydrologic connections from non-connected wetlands to streams is sparse, and the conditions for such connection are poorly known. Probably the best large-scale evidence is the long-term data collected in the prairie pothole region by Winter et al., However few such studies occur in the western U.S.
Crumpton	<p>The conclusion that in the case of non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel, connectivity and isolation varies within a watershed and over time is well supported by the scientific evidence.</p> <p>The conclusion that the literature reviewed does not provide sufficient information to document the connectivity of these systems is correct, but it should be noted that this is largely because the category includes a mix of wetlands that are truly geographically isolated and wetlands that are clearly connected to downstream waters. The report should attempt to provide guidance on how to distinguish these two categories (perhaps using soils and other indicators). The report distinguishes geographically isolated wetlands as surrounded by uplands but seems to include in this grouping all non-riparian/non-floodplain wetlands that do not outlet to a channel. This concept is introduced on lines 52-54 on page 3 of the <i>Introduction</i> and repeated throughout the report. It is well illustrated by Figure 3-18 on page 64 in section 3.4.2. Essentially the report places wetlands that spill over to a “swale” in the category of geographically isolated wetlands since swales can be “upland”. However, it would also include in this category prairie pothole depressions that spill over onto wetland flats or slope wetlands rather than to a channel. Wetland depressions that spill over to wetland systems (including wetland flats, slope wetlands or hydric swales) should be recognized as a separate category, distinct from wetlands that are completely surrounded by upland and thus more likely to be truly geographically isolated.</p> <p>52 or ephemeral streams that originate from them). In non-riparian wetlands that are not</p> <p>53 connected to the river network through a stream channel (i.e., geographically isolated</p> <p>54 wetlands and wetlands that spill into losing streams), connectivity varies</p> <p>55 geographically within a watershed and over time, making it difficult to generalize</p> <p>56 about their connections to, or isolation from, downstream waters. The literature we</p> <p>The report provides reasonable coverage of the relevant peer-reviewed literature on connection and isolation of non-riparian/non-floodplain wetlands to the downstream waters but does fall short in a few areas.</p>

	<p>The report fails to adequately address the effect of subsurface tile drainage on connectivity of these wetlands to downstream waters. The report recognizes that surface drainage and ditching can directly increase connectivity to downstream waters (for example lines 5166-5170 on pages 249-250 of section 5.8.3.1). The report states that “When potholes are artificially connected to streams and lakes through drainage, isolation is eliminated and they become important sources of water and chemicals” (lines 4984-4985 on page 242 in section 5.8.1). However, the report is apparently referring only to surface drainage. Little consideration is given to the importance of subsurface “tile” drainage which is ubiquitous throughout the Corn Belt and many other areas. The report mentions only briefly that “drains fitted at the bottom of potholes connected to shallow subsurface pipes often discharge to open ditches and streams” (lines 5170-5171 on page 250 of section 5.8.3.1) but is silent on whether this constitutes a direct connection to downstream waters. This is an extremely important issue and the report should clarify the role of subsurface tile drainage (and especially surface intakes to these systems) in providing a connection to downstream waters. Specifically, do surface intakes of subsurface drainage pipes (“tile drains”) provide a direct connection to downstream waters for what might otherwise be considered geographically isolated wetlands?</p> <p>5169     Ditches create new surface water outlets from potholes, allowing collected water to flow into</p> <p>5170     streams and rivers; drains fitted at the bottom of potholes connected to shallow subsurface pipes</p> <p>5171     often discharge to open ditches or streams (Ginting et al. 2000).</p> <p>The report in part uses HGM (hydrogeomorphic) wetland classification and could benefit from a review of the wetland classes in this system. Important HGM classes in the Prairie Pothole Region would include for example depressions, flats, and slope wetlands. This classification is useful in that it helps to illustrate connections and surface flow paths in these landscapes.</p> <p>The report should also provide information on the relationship between soils and wetland classes. Soils can be very useful in determining HGM wetland class, in identifying flow paths and connections, and potentially in distinguishing geographically isolated wetlands from depressions that are at least intermittently connected to downstream waters through wetland flats or slope wetlands.</p> <p>The report makes the important point that increased surface outflow and connectivity is expected in wetter portions of the prairie pothole but extends this analysis only as far as the Red River Valley and ignores the much wetter and more interconnected wetlands of the Des Moines Lobe (lines 1434-1437 on page 77 of section 3.4.6 and lines 5138-5143 on page 248 of section 5.8.3.1).</p>
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	<p>5138 connections. Authors have reasoned that the relatively wet and topographically low Red River  5139 Valley zone of the PPR should display greater surface water connectivity of potholes than either  5140 the Drift Prairie or Missouri Coteau zones. Furthermore, they suggest that stream density will  5141 impact the chance that pothole spillage connects to the larger river network. Thus, potholes in  5142 the Missouri Coteau, with its limited network of streams, should be more hydrologically isolated  5143 than potholes in the Red River Valley or Drift Prairie (Leibowitz and Vining 2003).</p> <p>1434 connections occurring between wetlands should be inversely proportional to local relief. Within  1435 the PPR, precipitation generally decreases from east to west, while relief generally increases.  1436 The easternmost physiographic region in the PPR is the Red River Valley, a relatively flat  1437 ancient lakebed (Lake Agassiz) having deep deposits of silt and clay. Water can pond easily on</p> <p>A broader analysis of this pattern for the Prairie Pothole is provided by Johnson et al. (2005. <i>Vulnerability of northern prairie wetlands to climate change. Bioscience</i> 55: 863-873). Their models of wetland water regimes suggest that spillover to downstream waters is a common occurrence in the wetter portions of the Prairie Pothole Region. For the Des Moines Lobe, spillover was expected in 87 years over a 95 year weather record. Because of the wetter climate, depressional wetlands on the Des Moines Lobe formed as interconnected systems with significant flow from upslope depressions through wetland flats to downslope depressions and from downslope depressions to receiving streams. In this regard, prairie potholes of the Des Moines Lobe differ from the more isolated basins that are typical of drier parts of the Prairie Pothole region. An analysis of soils illustrates these differences between the more interconnected wetlands of the Des Moines Lobe and the more isolated wetlands of the drier portions of the Prairie Pothole Region.</p> <p>The literature is for the most part cited and summarized correctly. However, in several places (line 1435-1468 and others), the report incorrectly describes the subregions of the Prairie Pothole Region, essentially ignoring the Des Moines lobe. This is the southeastern and wettest portion of the Prairie Pothole and as suggested above, its wetlands might be expected to have greater connectivity to downstream waters.</p>
<p><b>Cummins</b></p>	<p>The conclusions are supported by the scientific evidence.</p> <p>In general they are supported by the literature cited. However, I find this section very hard to evaluate objectively because the reason for separating out NRCWs as a class of connectivity is not clear. As noted in the underlined portion of the question above, there is no reason for this conceptual category.</p> <p>There was a lot of discussion at the Committee Meeting about a reorganization of the information that was presented in the Document. I think the general thrust of the recommendation would improve the Document <i>and</i> not require much, if anything, in the way of new information.</p>

	<p>The organization would not be levels of connectivity but rather functional classes of connectivity: hydrologic, physical (geomorphic), chemical (nutrients/pollutants), and biological (ecological). Within each of these classes there would be continua of connectivity described as probabilities. Namely spatial and temporal probabilities of degree of connectedness. As was suggested, a conceptual model could be presented for each. For example, ephemeral streams have a low probability of connectivity on any given day in any given year, whereas perennial streams have a near 100% probability of connectivity along the same time continuum. The more spatially separated streams and wetlands of various types are, the lower probability they will exhibit high connectivity on any time scale.</p> <p>This more functional approach would provide, I believe, a better frame work for handling the problem of conceptual models for isolated (surrounded by uplands) wetlands and allows for the concept that there are no examples of biological isolation, because migrations will always bridge hydrologic, physical, and chemical isolation.</p>
<b>Dodds</b>	<p>Yes they are. However, the authors could have made a stronger statement here. One way to look at the issue is that if a wetland is not connected at all to other waters, then the only output of water must be evaporation. If this is the case then wetlands must be saline because salts will collect. As many if not most of these wetlands are not highly saline, there is strong indication that most wetlands are indeed connected to downstream waters either directly or through groundwater.</p>
<b>La Baugh</b>	<p>The overall synthesis of the cited literature provided in the report supports conclusion 3 in general. Parts of the text would benefit from revision for clarification and technical accuracy, as noted below.</p> <ul style="list-style-type: none"> <li>• <b>Page 15, lines 336 to 344</b> – <u>What is the source of the definition of “geographically” isolated? Why is it necessary to distinguish between geographical and hydrological isolation? The issue of connectivity would seem to be a function of the movement of water (and as noted on page 49, lines 949 -950 – movement of biota) independent of “geography.” The reason for the introduction of the concept of geographic isolation is missing. Also missing is a literature citation for the statement that vernal pools and coastal depressional wetlands are incorrectly referred to as geographically isolated. Why does this distinction matter?</u></li> <li>• <b>Page 64, Figure 3-18</b> – <u>An inconsistency appears to exist between what is shown in part B and the definition of “geographical isolation” on page 15, lines 340 to 342. Why is the non-channelized swale considered to be upland? By the definition on page 15, the wetland is geographically isolated when completely surrounded by upland. In order for water to exit the wetland to the swale, would not the swale have to be topographically lower than the wetland proper and be adjacent to it? The point raised here simply reinforces the reason for the inclusion of geological isolation in the context of examining connectivity is unclear.</u></li> <li>• <b>Page 218, Table 5-3, second entry</b> – <u>Is soil permeability the major factor controlling whether or not a wetland loses water by surface versus groundwater? What about the</u></li> </ul>

	<p><u>importance of topographic setting with respect to the presence of channels or swales (see Figure 3-18B for example)?</u></p> <ul style="list-style-type: none"> <li> <p><b>Page 218, Table 5-3, fourth entry</b> - <u>The connection of a non-riparian wetland to other water bodies through groundwater flow involves a time component. Even if the groundwater flow system that hydraulically connects a non-riparian wetland with an adjacent surface-water body is simply a local flow system, time is a factor related to the influence of the wetland on the adjacent surface-water body. If the flow path is one such that a particle of water takes years, decades, or longer to travel down gradient to the surface-water body, that length of time needs to be considered in the determination of how much of an influence the wetland has on the adjacent surface-water body. It might be useful to note that even when the wetlands are connected hydraulically through groundwater time affects the influence of the wetland on adjacent water bodies. The subject of length of time of groundwater flow in relation to wetlands is presented in Winter and LaBaugh(2003) cited in the EPA report.</u></p> </li> <li> <p><b>Page 241, lines 4981 to 4982</b> – <u>The use of the term impermeable throughout the document can be confusing. In most cases it seems that the contrast is more likely one of rivers or wetlands in high- permeability terrain in comparison with those in low-permeability terrain. In the prairie pothole region some water does infiltrate the soil so it would be more precise to indicate the soils and the glacial till comprise low-permeability terrain.</u></p> </li> <li> <p><b>Page 250, line 5175</b> – <u>One factor that can change the chemical characteristic of prairie pothole wetlands is loss of sediment due to wind erosion during periods when wetlands become completely dry. This phenomenon is documented in LaBaugh et al., 1996, cited elsewhere in the document. Thus, unaltered wetlands with no surface outlet may also lose nutrients, sediment, and other chemical compounds during such episodes.</u></p> </li> <li> <p><b>Page 254, lines 5259 to 5265</b> – <u>One of the key factors affecting connections between prairie pothole wetlands and streams or river networks is the presence of ditches made by human activity. Mention of this is absent from this finding, even though ditching was noted in the supporting text that precedes this section.</u></p> </li> <li> <p><b>Page 254, lines 5266 to 5269</b> – <u>Ditching is a key factor enabling sediment, nutrients, and other chemicals that were present in wetlands to move to streams or rivers. The presence of a ditch to effect such transport is not conveyed in use of the phrase “Hydrologic sink or source functions of potholes can impact many features...” What exactly is meant by “multiple aspects of flow?” The concern here is that the finding is imprecise relative to what has been documented in the literature. In order for water to move across the land surface to a stream or river, either a surface connection needs to be made by a ditch or wetland water levels must rise to spill points in their basins that have a natural topographic path to a stream or river. Only when such hydrologic connections are made will water in the wetlands have the capability of transporting sediment or chemicals to streams.</u></p> </li> </ul>
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	<ul style="list-style-type: none"> <li>• <b>Page 256, lines 5311 to 5312</b> – <u>If the pools lie on impermeable substrates how does water infiltrate to form a shallow flow system? Perhaps the pools lie on low-permeability substrates rather than impermeable substrates. Also, if the substrate is impermeable, by definition it will not contain a surficial aquifer. A low-permeable substrate could contain a shallow groundwater system separated from a deeper regional aquifer by a confining bed.</u></li> <li>• <b>Page 270, lines 5617 to 5623</b> – <u>The content of the paragraph reinforces the need to provide a better definition of “geographically isolated,” as well as attribution to the source of that definition earlier in the document.</u></li> </ul>
<b>Rains</b>	<p><b>SUMMARY</b></p> <p>The conclusions are supported by the scientific evidence provided. This is the most difficult task for the authors, because hydrological and ecological connectivity are not fundamental tenets for these systems. However, I do have comments regarding some flaws and/or inadequacies in the scientific evidence provided as justification and regarding the wording of the conclusion, which I think soft-peddles the conclusion. (See, also, the detailed comments related to the conceptual framework in the section titled “Additional Reviewer Comments” below.)</p> <p><b>DETAILED COMMENTS</b></p> <p>l. 4004-4017: This is a confusing paragraph. At first, it seems like only depressional wetlands are going to be included, and it’s not until l. 4008 and beyond that other types of wetlands are mentioned. I suggest listing all of the types as a list in the first sentence, then clarifying the details in order thereafter.</p> <p>l. 4025-4098: You might consider wind transported snow as a special case of hydrological connectivity. In that regard, you might consider including Rains (2011), who showed that moraine, ice-scour, and dead-ice depressional wetlands serve as groundwater recharge focal points because aeolian-transported snow is trapped in the topographic lows in winter and then melts and recharges underlying groundwater immediately following breakup in late spring, with the net effect being that groundwater recharge rates in these depressional wetlands is 37%-332% of the broader surrounding landscape.</p> <p>l. 4053-4078: You might also consider discussing the special but very important case of groundwater flow-through wetlands. Groundwater flow-through lakes and depressional wetlands, where surface waters are a surface expression of broader groundwater phenomena, have long been recognized. Born et al. (1979) and Rains (2011) described groundwater flow-through depressional wetlands in glaciated landscapes, Sloan (1972) and Richardson et al. (1992) described groundwater flow-through prairie potholes in the northern prairie, and Murphy et al. (2008) described groundwater flow-through depressional wetlands in clay-rich soils with abundant desiccation cracks and other macropores. Rains et al. (2006) showed that vernal pools in central California are a special case, being groundwater flow-through wetlands supported by a seasonal perched aquifer that is unconnected to the underlying regional aquifers.</p>

	<p>1. 4100-4116: You might consider explaining why depressional wetlands are so good at storing surface water. Though water can be stored in uplands, too, surface-water storage in wetlands is more efficient than shallow groundwater storage in uplands, because wetlands have an effective specific yield of ~1.0 (i.e., the entire empty portion of the basin is available for storage) in most circumstances (Sumner 2007), while upland deposits have a specific yield of ~0.1-0.2 (i.e., only 10-20% of the deposits are voids available for storage) in most circumstances (Johnson 1967).</p> <p>1. 4145-4146: Hammersmark et al. (2008) showed that this dry-season baseflow ceased earlier when an incised river was restored to the historic floodplain. One of the reasons for this was that evapotranspiration was higher in the restored floodplain wetlands than in the previously drier floodplain uplands.</p> <p>1. 4390-4398: This is the first occurrence of this list, which recurs a few times hereafter. In all cases, you should add that wetlands can be connected by groundwater connections to one another and to nearby streams.</p> <p>1. 4401-4402, 1. 4415-4425: I lump these specific lines together in one comment to make an important point. In the first case, you state in clear, concise, and unequivocal terms that riparian and floodplain wetlands are highly connected to river systems. In the second case, you dither for a few paragraphs, then finally get around to saying that non-riparian and channel origin wetlands might be connected to river systems under certain circumstances. You are correct; however, by dithering and then only vaguely supporting the idea that non-riparian and channel origin wetlands might be connected to river systems, and then only under certain circumstances, I think that you soft-peddle what we know about the flow of water across landscapes. To be honest, all hydrologic systems are interconnected to some degree or another—that’s why hydrologists refer to the entire water cycle environment as the hydrosphere. All we’re really debating here is the degree to which non-riparian and channel origin wetlands are connected to river systems. There is no bright line between connected and isolated, there is only a vague gray area where we might choose to transition from their being a significant nexus to their not being a significant nexus. This was a central point to the arguments by Nadeau and Rains (2007), and I think it’s an important argument to make here, because the scientific evidence clearly supports that position.</p> <p>1. 5295-5298: Vernal pools aren’t really located in what most people in the West would consider “coastal areas of the western United States”. For example, Rains et al. (2006, 2008) were working in the Central Valley of California, in vernal pools that were 2-3 hours drive from the coast. I think it more correct to just say “the western United States” or “Mediterranean-like climates in the western United States”.</p> <p>1. 5314-5318: You might consider adding Rains et al. (2006) to the references at the end of this sentence.</p> <p>1. 5385-5387: You might consider adding Rains et al. (2006) to the references at the end of this sentence.</p> <p>1. 5401-5412: There is a key difference between these two types of vernal pools that you have missed. The vernal pools on clay-rich soils are perched surface-water systems; the</p>
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	<p>vernal pools on hardpan soils are perched surface-water and groundwater systems. This makes them behave very differently from a hydrological perspective.</p> <p>Table 5-2, Table 5-3: These tables provide are concise synthesis. Can one be made for rivers?</p>
<b>Richardson</b>	<p>The conclusions are supported and carefully reviewed. The connection is supported for some cases, but not for all, so I agree that one cannot categorically conclude that this class of wetlands is connected. The role of isolated wetlands in storing water that may reduce runoff intensity and storm-flow generation to streams is a good idea that deserves further study to empirically back up the simulations presented. Likewise, the contributions of these isolated wetlands on transformation and storage of nutrients, thereby preventing their transport to rivers could be another important mechanism by which these wetlands contribute to navigable rivers and deserves field trials. The uncertainties associated with the connections of non-floodplain wetlands are carefully acknowledged for the examples, especially for the example of coastal bays, which have some indications of connections, but not strong, and the authors are careful to address that. The prairie potholes likewise occupy a continuum, but most have evidence of some connection. The distinction made to clarify geographic isolation from functional connectivity is useful.</p>
<b>Snodgrass</b>	<p>The authors use the indirect argument that headwater streams are widespread and high rates of a number of ecological processes have been measured; therefore, these systems must have an impact on downstream rivers. In fact, this is a general approach that is well founded (lines 450 through 452). However, in places the authors indicate both pieces of this argument are in place for geographically isolated wetlands—high rates of nutrient removal and extensive coverage of geographically isolated wetlands—but then only report that the effects of this removal are not reported for downstream waters (see lines 313 through 328). Although conclusion number 4 below begins to address this issue, I think the argument could be made more forcefully. In fact, what we know about the effects of impervious surface (only mentioned briefly on line 1360) makes a strong argument for a large impact of wetland loss in any watershed where wetlands cover a relatively large area—if 25% of a watershed is covered in wetlands and those wetlands are converted to impervious (or less pervious) surfaces then there will be large impacts on streams, stream hydrology, geomorphology, ecosystem function, and biological communities, ultimately affecting downstream rivers (Paul and Meyer, 2001; Welsh et al., 2005). The same argument for agricultural systems can be found on lines 1394 through 1400. Given that the depressions that form these wetlands are areas of low or no surface runoff, a principle we have put to use in our design and management of stormwater runoff using stormwater management ponds, it is highly likely that loses of geographically isolated wetlands have a disproportionally large influence on downstream waters compared to upland habitat loss. Therefore, it seems that in many areas (e.g., Atlantic and Gulf Coastal Plains) the indirect argument for connection and influence of geographically isolated (but not hydrologically isolated) wetland to downstream streams and rivers is stronger than the authors indicate with this conclusion. See my general post meeting comments for further discussion of this issue.</p> <p>The authors discuss “isolated wetlands that have no hydrological connection to other water</p>

	<p>bodies” (lines 351 and 352) in a number of places in the manuscript. I am not aware of a hydrological study of an isolated wetland that has not shown some degree of connection to ground waters (either through recharge or discharge and recharge). If such studies exist it might be a good idea to give an example and indicate the number of studies that have found no connection. Additionally, lines 1206 through 1209 describe geographically isolated wetlands that recharge deep ground water or that occur in isolated terminal basins where “evapotranspiration is the only form of water loss.” I am not familiar with these systems as I work in areas where extensive shallow groundwater connections are common. There is no citation with these descriptions either. It would be nice to describe how many studies fit these descriptions and if they are limited to desert springs and lake systems such as the Great Salt Lake. Figure 3-18 makes it seem like these systems can be small and similar to geographically isolated wetlands.</p> <p>Also related to the above comments, in the case study of Carolina bays the authors suggest that groundwater and surface water connections of bays to streams are still debated. However, all of the studies to date have documented groundwater connections and the loss and recolonization of these systems by fishes suggests frequent surface water connections for bays up to 700 m from intermittent streams (see Snodgrass et al., 1996 and summary argument in Sharitz 2003). Given these considerations it appears that for Carolina bays at least, connectivity is the norm and isolation rare.</p> <p>On lines 3521 through 3522 the authors indicate that they “consider any evidence of connectivity with a stream to be evidence of connectivity with the river and other downstream waters.” Later (on lines 4097-4098) the authors indicate wetlands that feed losing streams cannot be considered channel wetlands. However, in the previous chapter the authors argue that losing streams should be considered connected to more permanently flowing downstream waters.</p>
<b>van der Valk</b>	<p>Yes. This category of wetlands, however, contains a mix of wetland types that is so broad and heterogeneous that no definitive conclusions about their hydrological connectivity to rivers could ever be drawn for the entire category. There are situations where a case for hydrologic connectivity of wetlands in this class to rivers can be made using soils data, e.g., prairie potholes in Iowa. Although definitive data are missing in most cases, it can be inferred that these types of wetlands are connected biologically to rivers and vice versa in many, if not all, cases.</p>
<b>Wipfli</b>	<p>Question is outside my area of expertise.</p>

- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.

Reviewer	Comments
Cooper	See comment 3a) above.
Crumpton	See comment 3a) above.
Cummins	This report includes the most relevant peer-reviewed literature on those topics, including evidence of connectivity and isolation as presented. However, if a different organization of the report is adopted, as discussed above, a reorganization of the references cited would be needed.
Dodds	<p>Yes, this is made very clear. Isolation is certainly an issue mostly with the biological data, and they cover this well.</p> <p>There has been a good amount of work on groundwater connections in the Highland Lake District of Wisconsin, and these connections include wetlands. One reference on this might be Hunt, R.J., Strand, M. &amp; Walker, J.F. (2006) Measuring groundwater-surface water interaction and its effect on wetland stream benthic productivity, Trout Lake watershed, northern Wisconsin, USA. <i>Journal of Hydrology</i>, 320, 370-384.</p> <p>There is a huge amount of work on hydrologic and chemical connection in the Everglades. This should probably be covered a bit better here.</p> <p>Line 4835. Why all of a sudden a section on human alterations here, where there are other human alterations throughout? This section is just a bit inconsistent with the rest of the report.</p>
La Baugh	<ul style="list-style-type: none"> <li>• Arndt and Richardson discuss hydric soil development in prairie pothole wetlands (Arndt, J.L., and Richardson, J.L., 1988, Hydrology, salinity, and hydric soil development in a North Dakota prairie-pothole wetland system. <i>Wetlands</i>, v. 9, p. 93-108) but are not included in the references.</li> <li>• <u>A useful reference regarding wetland soils and water flow in a variety of landscapes is Richardson, J.L., and Vepraskas, M.J., editors, 2001, <i>Wetland soils: genesis, hydrology, landscapes, and classification</i>. Lewis Publishers, Boca Raton, Florida, 417 p.</u></li> <li>• <b>Page 283, lines 6053 to 6056</b> – <u>Entry for the cited literature source is not complete regarding publication information.</u> The correct, complete entry should be revised as follows –Dickinson, J.E.....2020...Middle San Pedro Watershed, Southeastern Arizona. U.S. Geological Survey Scientific Investigations Report 2010-5126, 36 p. <a href="http://pubs.usgs.gov/sir/2010/5126/">http://pubs.usgs.gov/sir/2010/5126/</a></li> <li>• <b>Page 325, lines 7588 to 7593</b> – <u>Entries for the cited literature source are not complete regarding the publication information.</u></li> </ul>

	<p>The correct entry for the Vining 2002 should be revised as follows – Vining, K.C., 2002....Water Years 1981-98. U.S. Geological Survey Water-Resources Investigations Report 02-4113, 28 p. <a href="http://nd.water.usgs.gov/pubs/wri/wri024113/">http://nd.water.usgs.gov/pubs/wri/wri024113/</a></p> <p>The correct entry for Vining 2004 should be revised as follows Vining, K.C., 2004....North Dakota and Minnesota. U.S. Geological Survey Scientific Investigations Report 2004-5168, 28 p. <a href="http://pubs.usgs.gov/sir/2004/5168/">http://pubs.usgs.gov/sir/2004/5168/</a></p>
<b>Rains</b>	See comment 3a) above.
<b>Richardson</b>	The literature reviewed is excellent and represents state-of-the-science.
<b>Snodgrass</b>	The issues discussed above concerning the importance of isolation for headwater stream communities also applies to geographically isolated wetlands. As the authors clearly review, isolated wetlands are periodically connected by surface waters to downstream areas that may provide sources of colonist that establish populations in wetlands. These populations can have large effects on wetland communities through predation, and trade-offs among the competing demands of surviving desiccating conditions and predation pressures creates adaptations to narrow ranges of hydrological and predator community conditions (Wiggins et al., 1980; Wellborn et al., 1996). Therefore, alteration of the isolation or connection of wetlands to downstream communities has the potential to alter biodiversity associated with isolated wetlands. See Snodgrass et al. (2000) for further discussion in relationship to wetland regulations.
<b>van der Valk</b>	Yes. It does a good job of reviewing the published literature. However, it is somewhat ambivalent about the interpretation of some of the literature on “clusters” of wetlands. Although wetlands within a cluster evidently are linked, presumably by groundwater flows, they are considered only linked if there is a surface water connection from one wetland in the cluster to a river. The potential for groundwater connections between isolated wetlands and rivers is never examined. That wetlands like prairie potholes are connected by groundwater flows is well documented. That similar groundwater flows can also connect them to rivers is at least highly probable for some prairie potholes in less hummocky terrain.
<b>Wipfli</b>	Question is outside my area of expertise.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

<b>Reviewer</b>	<b>Comments</b>
<b>Cooper</b>	See comment 3a) above.
<b>Crumpton</b>	See comment 3a) above.
<b>Cummins</b>	Yes, the literature was cited and summarized correctly.

<b>Dodds</b>	<p>Yes, this is cited and summarized correctly.</p> <p>Line 5177 the word detrimental is loaded, if it is a natural accumulation, then not quite sure how it is viewed as detrimental.</p> <p>I am not really clear on how vernal pools are substantially different than the prairie potholes for the purposes of this document. The criteria on 5345 could apply to many of them.</p>
<b>La Baugh</b>	<ul style="list-style-type: none"> <li>• Literature pertaining to the overall topic and prairie pothole wetlands was summarized correctly in general. Areas requiring clarification are noted above in 3a.</li> <li>• I am not familiar with all of the literature cited in the document regarding the relation of oxbow lakes, Carolina and Delmarva Bays, and vernal pools to their connection with and influence on downstream rivers, therefore I am not able to judge whether or not all of the cited literature pertaining to those types of wetlands was summarized correctly.</li> </ul>
<b>Rains</b>	See comment 3a) above.
<b>Richardson</b>	The summary of the literature is very good and the authors have appropriately represented the collective evidence.
<b>Snodgrass</b>	The literature that was reviewed appears to be interpreted correctly and cited appropriately.
<b>van der Valk</b>	Yes. However, the use of soil maps, however, to demonstrate ephemeral surface water linkages between isolated wetlands like prairie potholes and streams is not fully explored. See above. Likewise the possible connection of isolated wetlands to rivers by groundwater flow is largely ignored.
<b>Wipfli</b>	Question is outside my area of expertise.

4. This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.

a) Is this conclusion supported by the scientific evidence?

Reviewer	Comments
Cooper	The contribution of streams and wetlands on downstream waters is well known for flood water retention (the studies by Novitski 1978 in Wisconsin should be added). Denitrification has been shown in many wetlands. However few other functions have been conclusively demonstrated for many wetland types.
Crumpton	<p>The conclusion that in the aggregate, a class of streams or wetlands might have a substantial effect on downstream waters even though the influence of an individual stream or wetland might be small is clearly supported by the scientific evidence (and by simple common sense).</p> <p>The report provides sufficient coverage of the relevant peer-reviewed literature on this topic although that literature is by design spread throughout the report in the treatments of streams, riparian/floodplain wetlands, and non-riparian/non-floodplain wetlands.</p> <p>The literature relevant to this topic was cited and summarized appropriately although its dispersion throughout the document makes it less easily accessible than that of the other topics.</p>
Cummins	The conclusions are supported by the scientific evidence.
Dodds	Yes, this is a very important point of this document. This point is actually true for any non-point pollution source, and the entire field of watershed management and TMDL's is based on this idea. Once the systems are known to be connected to receiving waters, then it is a clear fact that small individual systems might have a large effect in aggregate.
La Baugh	In the section 6 of the document containing the set of conclusions (pages 266 to 271), the conclusion noted as 4 above was not presented. Nor was a fourth conclusion presented in Executive Summary at the beginning of the report. The absence of a fourth conclusion in the report, accompanied by supporting statements of key findings to support that conclusion, make answering this question and the following questions problematic.
Rains	<p><b>SUMMARY</b></p> <p>To be honest, I don't see where you make this case explicitly at all. I do think that it is true, or at least that it can be true. For example, there's no doubt that obliterating a single headwater stream high up in the watershed will have no measurable effect on the large, mainstem river where it discharges to the ocean, but there's equally no doubt that obliterating all of the headwater streams in the watershed will have a measurable and</p>

	<p>catastrophic effect on the large, mainstem river where it discharges to the ocean. Justice Kennedy, in his opinion in <i>Rapanos v U.S.</i> (2006), would seem to agree. I do think that the basic pieces are in this document to make that case, but I think it important that you explicitly make this case, both throughout the document (e.g., in a paragraph or section when discussing streams, riparian and floodplain wetlands, and non-riparian and channel origin wetlands) and in a single standalone section, perhaps referencing the voluminous cumulative effects literature (e.g., Bedford and Preston 1988, Lee and Gosselink 1988, Childers and Gosselink 1990, Johnston 1994, and many others). The latter could be done toward the end of the conceptual model, after you have shown landscape-scale connectivity between all of the disparate pieces separately discussed in this document. The former could then be done with examples within the individual discussions of the disparate pieces discussed in this document. You already do some of this—for example, you do discuss the role that depressional wetlands play in storing water and reducing stormflows (l. 4100-4116)—but you probably should do more and more explicitly state the point that you are trying to make here whenever you do.</p> <p>There are numerous examples of this with regards to flood storage that you could add to those that you already have discussed. Non-floodplain wetlands temporarily store surface water, thereby attenuating and translating flood peaks in downstream river networks (Haan and Johnson 1968, Hubbard and Linder 1986). This phenomenon is so well known that rainfall-runoff models typically have a step when a storm begins where rainfall is abstracted and put into depressional storage and is unavailable for runoff throughout the remaining storm (McCuen 2005). However, storage capacity is a finite quantity that can be exceeded, suggesting that flat and depressional wetlands will have the greatest effect during smaller storms (Haan and Johnson 1968). In fact, ephemeral surface-water connections occurring immediately following larger storms are an indication that storage capacity has been exceeded and subsequent water is immediately discharged (Rains et al., 2006, Rains et al., 2008).</p> <p>There are also implicit examples of both flood storage and other processes that can be inferred from the literature. Depressional wetlands can focus groundwater recharge. As described elsewhere, Rains (2011) showed this to be the case for moraine, ice-scour, and dead-ice depression in southwest Alaska. He did not specifically upscale—necessary spatial data were lacking—but he did show that these types of wetlands are perhaps the most numerous and conspicuous types of wetlands in these environments, implying that, though the individual effect of one wetland may be negligible, the cumulative effect of the many thousands of wetlands must necessarily be important. In this case, the effect is implicit, not explicit, but you could nevertheless make this point more strongly by explicitly stating this implicit assumption.</p>
<b>Richardson</b>	Given the preponderance of small streams and wetlands that are not navigable in and of themselves, they in aggregate do contribute enormously to navigable systems. The conclusions drawn by the authors are sound and well supported by the literature.
<b>Snodgrass</b>	Yes the report clearly supports the idea that some wetlands and streams (if not all) make substantial contributions to the structure and functioning of downstream waters.

<b>van der Valk</b>	For streams, this conclusion is self-evident and is supported by the literature. For isolated wetland complexes, there are only a few relevant studies. Consequently, although it may be true, it is more of a conjecture than a fact. What exactly constitutes “a cluster of small wetlands”? How do you draw the boundaries around a cluster? See above.
<b>Wipfli</b>	Absolutely yes. This is a key point about headwaters and downstream waterways that unfortunately can easily be overlooked, and I was pleased to see this addressed. Individually, small streams do generally not have large influences by themselves on downstream processes, but in aggregate they tremendously affect riverine networks at the watershed scale.

**b) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**

<b>Reviewer</b>	<b>Comments</b>
<b>Cooper</b>	See comment 4a) above.
<b>Crumpton</b>	See comment 4a) above.
<b>Cummins</b>	This report includes the most relevant peer-reviewed literature on those topics, including evidence of connectivity and isolation. This question has already been addressed in detail under the other charge questions. There seems little reason to simply transfer those comments (especially Charge Question 1) to this spot. I find the charge question redundant. Whereas the first three charge questions more or less apply sections 3, 5 (5.1-5.3) and 5.4 of the report, respectively. There is no separate section that corresponds to Charge Question 4. If one uses the find option in Word and inserts intermediate or ephemeral streams or small wetlands in the search, one or both of these appear in essentially every sub-section of the entire report. In reading the report I concluded that these entries were accompanied by appropriate citations. The comments provided under Question 3) apply here as well. If the Report was organized functionally, this section would be subsumed under each of the functional conceptual models.
<b>Dodds</b>	As far as I know, yes.
<b>La Baugh</b>	Insufficient information was provided to enable an answer to the question.
<b>Rains</b>	See comment 4a) above.
<b>Richardson</b>	The review has covered a comprehensive set of literature relevant to the topic.
<b>Snodgrass</b>	Yes, if the references mention above are included.
<b>van der Valk</b>	Yes, the most relevant literature has been reviewed in the report. However, the relevant literature on wetland soils that demonstrates how connected some putatively isolated

	wetlands like prairie potholes really are is not adequately explored. See Miller et al. (2012) in Wetland Ecology and Management.
<b>Wipfli</b>	Yes, the report includes the relevant scientific literature on the cumulative effects of headwaters.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

<b>Reviewer</b>	<b>Comments</b>
<b>Cooper</b>	See comment 4a) above.
<b>Crumpton</b>	See comment 4a) above.
<b>Cummins</b>	The reviewed literature was cited and summarized correctly, <i>or</i> relevant comments were covered under the first three Charge Questions (e.g., comments about adaptations by invertebrate life cycles to accommodate periodic drying, in which the annual predictable seasonal flows of intermittent streams have more taxa adapted to the condition than in ephemeral streams, in which annual flows can only be described in terms of probabilities).
<b>Dodds</b>	As far as I know, yes.
<b>La Baugh</b>	Insufficient information was provided to enable an answer to the question.
<b>Rains</b>	See comment 4a) above.
<b>Richardson</b>	The authors have made a very thorough search of the literature for appropriate references and have drawn appropriate conclusions, including pointing out any uncertainties about the conclusions possible.
<b>Snodgrass</b>	Yes, again with the consideration of comments included above.
<b>van der Valk</b>	Yes. The problem is not with the interpretation of the literature but with creating an artificial category of wetlands that contains so many different kinds of wetlands that no general conclusion could ever be drawn for the entire category.
<b>Wipfli</b>	Yes, to the best of my knowledge the literature on this topic was cited and summarized thoroughly and correctly.



## **Additional Reviewer Comments**



## Additional Comments Submitted by Dr. David J. Cooper

### Literature Cited

Novitzki, RP. 1978. Hydrologic characteristics of Wisconsin's wetlands and their influence on floods. Pp. 377-388, in P. Greeson, J. Clark, J.E. Clark (eds). Wetland functions and values: the status of our understanding. Proc. National Symposium on Wetlands. Am Water Res Assoc, Minneapolis MN.

Thomas C. Winter, Judson W. Harvey, O. Lehn Franke, William M. Alley. 2008. Surface and Ground water, a single Resource. USGS Circular 1139.

Hauer, F. R., Cook, B.J., Gilbert, M. C., Clairain, Jr., E. C., and Smith R. D.. 2001. The Hydrogeomorphic Approach to Functional Assessment: A Regional Guidebook for Assessing the Functions of Riverine Floodplain Wetlands in the Northern Rocky Mountains. Special Publ. WES, USCOE, Vicksburg, MS. p.255.

Hauer, F. R., Cook, B.J., Gilbert, M. C., Clairain, Jr., E. C., and Smith R. D. 2000. A regional guidebook: Assessing the functions of intermontane prairie pothole wetlands in the northern Rocky Mountains. Special Publ. WES, USCOE, Vicksburg, MS. p.189.

THREE papers (PDFs provided) that you might consider referencing as they present original data on hydrologic connectivity on ephemeral and intermittent streams to riparian and wetland ecosystems

Shaw, J. and Cooper, D.J. 2008. Watershed and stream reach characteristics controlling riparian vegetation in semiarid ephemeral stream networks. *Journal of Hydrology* 350:68-82.

Westbrook, C., Cooper, D.J., and Baker, B. 2006. Beaver dams and floods in controlling hydrologic processes of a mountain valley. *Water Resources Research* 42: W06404, doi:10.1029/2005WR004560

Wurster, F.C., Cooper, D.J., and Sanford, W.E. 2003. Stream/aquifer interactions at Great Sand Dunes National Monument, Colorado: Influences on interdunal wetland disappearance. *Journal of Hydrology* **271**:77-100.



### **Additional Comments Submitted by Dr. William G. Crumpton**

My additional comments relate primarily to charge questions 3.

Much of our panel's discussion seemed to focus on issues related to connectivity and while connectivity is important, it is in many ways more important to consider evidence of influence. This could be especially true in the case of "geographically isolated wetlands". In fact, the influence of "geographically isolated" wetlands could be increased by some degree of isolation, for example in the case of sediment retention and flood storage. Isolated depressional wetlands that are connected to downstream waters only during relatively infrequent storm flows could exert substantial influence on sediment transport and storm flows to downstream waters in part due to the relative isolation of these depressions from those downstream waters. Influence does not require a direct connection and "geographically isolated wetlands" could certainly alter material fluxes to downstream waters. Some of the effects of "geographically isolate wetlands" could be quantified based on available literature as has been done for tributary streams (for example an estimate of the flood storage volume of isolated depressions based on published values of their areal extent (for example using the estimates of Miller et al., 2009 for Iowa).

The apparent uncertainty over the connectivity of "geographically isolated wetlands" could be greatly reduced and the issues clarified by using an HGM approach to explicitly considering the links between wetland soils and hydrology. Wetland soils and hydrology are inextricably linked and soils can help in interpreting sources, pathways and frequency of water movement through wetlands and between wetlands and downstream waters. The NRCS technical note on "Soil Hydrodynamic Interpretations of Wetlands" is a very useful resource for this.

The report needs to clearly define and discuss issues related to cropped wetlands. Prior converted cropland and farmed wetlands are two distinct categories of wetland defined by the Food Security Act that have important implications with respect to both wetland protection and agricultural production. The 1985 Farm Bill established two categories of cropped wetlands, prior converted cropland and farmed wetlands.

*Prior converted cropland:* Wetlands that had been sufficiently drained prior to December 23, 1985 are referred to as prior converted cropland and are not treated as wetlands under the Swampbuster provisions of the 1985 Farm Bill. There are no USDA restrictions on further improving or enhancing drainage on prior converted cropland.

*Farmed wetlands:* Wetlands that had not been sufficiently drained prior to December 23, 1985 are referred to as farmed wetlands and are afforded protection under the Swampbuster provisions of the 1985 Farm Bill. There are restrictions on further improving or enhancing drainage on farmed wetlands. Farmers who improve the drainage of a farmed wetland beyond the "scope and effect of the original drainage" could lose all USDA program benefits or face penalties. These penalties or loss of benefits can cost landowners tens- or even hundreds of thousands of dollars.

The report needs to clearly define and discuss the issues related to subsurface tile drainage and how that influences connectivity of "geographically isolated wetlands" to downstream waters. In much of the Corn Belt, subsurface tile drainage systems transport most of the water that leaves agricultural watersheds. For

systems with surface intakes, tile drains could provide a direct connection to downstream waters. Regardless of one's opinion over the importance of this connection, it is unacceptable to ignore this issue in a report that addresses the connectivity and influence of wetlands on downstream waters.

**Additional Comments Submitted by Dr. Kenneth W. Cummins**

<u>Page</u>	<u>Line(s)</u>	<u>Comments</u>
2	28	... plants, microorganisms, and...
4	81	replace <i>lack</i> with back
8	176	...series of complex physical, chemical, and biological alterations...
10	223	... lakes and lakes and reservoirs that form nodes in river systems.
12	261-2	...of sediment and organic matter... before they enter...
13	306-8	The impacts ... habitat, and ecology. The concept discussed in 11, 253-60 also applies here.
15	334	...and invertebrates and vertebrates between... (fish and amphibian eggs have been isolated from migratory ducks feet)
17	398	... the term... Then why use it?
19	424	...oxbow lakes, “node” and pater noster lakes
20	443	... scientific community... not those ignoring non-peer reviewed literature. Also, the statement about peer reviewed literature only being used is not true – p 311, 7055, National Research Council 2002 reference was not peer reviewed literature.
21	477-8	Again, I would argue that this report has a more thorough and unbiased literature review than most “peer reviewed” papers.
25	539	First Vannote et al., 1980 citation. Introduce River Continuum Concept phrase used therein.
25	546	Fig. 3-2. You need a magnifying glass to distinguish ephemeral streams.
27	583	Use an acronym for riparian/floodplain wetlands (R/FWs) or spell out non-riparian and channel origin floodplains (NRCWs). Use acronym for both or spell out both throughout the document.
28	661-2	See comment at 20, 443 above.
33	689-90	...and references therein). This is a useful phrase to add where warranted because it indicates at least a partial review of the subject is included; could be useful other places in the report.
34	699	...precipitation and are not seasonally controlled.
34	715	...Hunter et al., 2005) and have major consequences for the distribution and seasonality of stream biota.
39	774	Fig. 3-10 has a much better representation of ephemeral streams than Fig. 3-2 (25, 546).

42	826	Delete <i>has</i> .
48	929-31	This is another argument for using link number. (see 24, 531; introduced at 122, 531 as useful but probably should be introduced here.
50	964	Vannote et al., 1980 should also be cited here.
51	1001	...be eaten by other invertebrates and by aquatic vertebrates, especially juvenile fish that eventually ...
51	1001	Delete <i>further</i> ; ambiguous.
52	1006	Fig. 3-14. This is an interesting take on the original Vannote et al., 1980 conceptual model. Perhaps a citation or two would be warranted here.
53	1017	...basin can be transported back to a river only by terrestrial (over land) movement and not by a hydrological pathway.
54	1047-8	...100 year floodplain. Introduce the concept of recurrence intervals (it appears later in the report.
56	1104	A statement is warranted about the “man-made paving” of essentially all urban watersheds in the U.S. resulting in quick flow as the rule.
59	1139	The Metolius River emerges and immediately assumes the ecological characteristics of a fourth-order river, with no headwater biological inputs and constant year around flow and temperature that completely alters life history patterns typical for streams of the region. (Fig. 3-15E; 57, 1105.)
61	1180	Define stream power (math formula) here or elsewhere.
63	1215	Fig. 3-17. Perhaps point out that C fits the pattern of quick flow for “paved” urban stream watersheds.
65	1240-42	See comment for 11, 253-60.
66.	162	Fig. 3-19. The use of link number can be seen in the figure. The trellis watershed is a third-order with a link number of 13 and the fourth-order dendritic watershed has a link number of 14. Riparian-dependent headwater ecological effects would be greater in the third order watershed.
73	1344	...Eikeland 1988, <i>add</i> Rader, 1997, ... [Rader, R. B. 1997. A functional classification of the drift: traits that influence invertebrate availability to salmonids. Can. J. Fish. Aquat. Sci. 54:1211-1234.]
74	1363	...movement and alter ecosystem function as in the case in which stream bank stabilization is accomplished by planting non-native willow to replace various species of alder. Alder (nitrogen fixers) litter is utilized at 5 to 10 times the rate of willow in headwater streams.

- 74 1374 ...al. 2011) and form a discontinuity in the normal stream-order related progression in stream ecosystem structure and function. (Ward, J. V. and J. A. Stanford (eds.). 1982. The ecology of regulated streams. Plenum, N. Y. 398 p.
- 81 1151 ...and ephemeral streams, even though these watershed represent only ??% (small) of the land area of the United States.
- 82 1517-18 Another argument for link number inventory.
- 82 1519-30 Make it clear that stream order is a geomorphic classification and *not* a blue line map criterion .If the tenets of connectivity in this report are to be honored, development of new watershed concepts and advancement in research and land management plans must not be blue line map based.
- 83 1551-53 As per the statement on 82, 1526 (...Despite this underestimation...), this raises important questions about the data.
- 85 1604-06 Again, this might be a useful approximation, but it shows that, in general, map blue line analysis cannot be used to clarify the actual physical, chemical, and, especially biological, importance of geomorphic first-order channels in a watershed.
- 85 1608 ...and river flows, as long as headwater streams are defined as second-order channels.
- 87 1630 ...return interval... First mention of recurrence interval. Here, or elsewhere it should be defined (calculation method) and its utility discussed.
- 91 1706 ...Suspended sediment... The question of suspended fine particulate organic particles should be acknowledged. FPOM is a significant contributor to turbidity (first to be entrained on the rising limb of the hydrograph and the last to settle out on the falling limb) and biologically by far the most important component of the suspended load.
- 93 1763 ...inorganic + organic... First mention of the organic component; should appear earlier.
- 94 1796 LWD in stream of the western Cascades in Oregon measured to have been in place for over 100 years.
- 96 1838 ...important habitat for aquatic life... Not just habitat; LWD has a major role as a long term source of slowly processed DOM and FPOM that is utilized by stream microbes and invertebrates.
- 97 1858 ...diel changes typical of intermediate sized streams... and rivers. Larger daily temperature excursions in mid-sized rivers is one of two reasons proposed (Vannote et al., 1980; orders 4-6) for the usually maximized biological diversity of these rivers. (Aquatic organisms have differing temperature optima, and a wide daily range of temperature excursion provides more species to spend at least part of every 24 hours in their optimum range.)
- 100 1915 ...chemical linkages through open cycle spiraling.

- 107 2088 ...terrestrial plant litter... (in addition to leaf litter, other riparian plant parts can dominate seasonally, e.g., catkins.)
- 108 2106 Cite Petersen et al., 1989. [Petersen, R.C., K.W. Cummins, and G.M. Ward. 1989. Microbial and animal processing of detritus in a woodland stream. Ecol. Monogr. 59:21-39.
- 109 2113 In this reference (and Vannote et al., 1980, and most of the other related ones I know of) headwater streams would be orders 1 – 3.
- 112 2187 .....downstream (Petersen et al., 1989, Gomi et al., ...
- 112 2198 ...et al., 2007) or in spring when other plant parts are shed, e.g., bud scales, flowers, catkins).
- 113 2219 ...et al., 2005). Diatoms continue to photosynthesize and invertebrates continue to feed and grow at 0°C. In fact, the majority of shredders accomplish all of their growth in the winter and remain inactive all summer in streams in forested areas (Cummins et al., 1989).
- 114 2235 The main point of the note here is that it should be acknowledged that connectivity can be on a diurnal scale as well as longer time periods. Weekly grab samples for DOC at 10 locations throughout the Augusta Creek were taken in southwestern Michigan for two years. Locations were sampled in sequence each week from 1 through 10 in the same sequential order. The data showed significant differences in DOC concentrations between the sites. When samples were taken every 2 hours over 24 hours at 1 site, the difference in the values were equal to the difference in the values between the 10 sites over 2 years. What appeared to be differences between sites over the 2 years were due entirely to the time of day when the samples were taken which was essentially the same each week because of the regular sampling schedule.
- 119 2374 Many invertebrates have life cycles that “expect” (are adapted to) dry and/or wet and /or hot or cold periods for the completion of their life cycles. Some may even require these periods.
- 120 2380 .....drifting insects (Rader 1997, Nakano...
- 120 2388 ...et al., 2006) and diel invertebrate behavioral patterns that are independent of flow (Rader 1997).
- 122 2439 ...higher prey and lower predator densities...
- 129 2605-06 Most often the *only* shrubs and trees in grassland biomes are along the water courses. This has significant implications for the in-stream biology (e.g., shading, litter inputs).
- 135 2737-38 flooding and drying..., spur successional sequences. Flooding is just as important in forested streams in resetting algal succession.

137 2765 ...surprisingly rapid. Why surprising? This is merely an example of the adaptation one would expect.

138 2808 ...was once limited by floods,... Is there post glacial evidence for this? Or, is “once” merely before agriculture cut the prairie?

146 2470 The functional feeding group (FFG) for categorizing freshwater invertebrates (e.g., Cummins and Klug 1979, Merritt et al., 2008) should be used (and defined) throughout the Report. There is a large literature extending over 30 years that utilizes this functional categorization on a world- wide basis (e.g., Cushing et al., 2002). The FFG meshes well with the concepts of connectivity.

Arguably, the best indicator of normal (statistically probable) linkage (coupling) between riparian vegetation and stream biota is the presence of invertebrate shredders (e.g., Cummins and Klug 1979, Grubbs and Cummins 1996, Merritt et al., 2008). The sequence is well known and has been demonstrated around the world (Cushing et al., 2006): 1) Riparian leaf is entrained in freshwater system; 2) leaf leaches DOM (up to 40 % of dry mass); 3) leaf rich in carbon, lower in nitrogen, colonized by hyphomycete fungi (and bacteria), leaf species vary significantly in the length of time required for hyphomycetes to develop hyphal growth in leaf matrix – termed conditioning; 4) shredder invertebrates seek out and feed on leaf or parts of leaf highest in hyphomycete biomass; 5) shredder feeding produces large amounts of FPOM (< 1 mm particle size feces and leaf fragments); 6) shredder feeding and temperature (number of degree days) accurately predict the period required to process a leaf from a given species of riparian plant (e.g., Petersen and Cummins 1974).

[Grubbs, S.A. and K.W. Cummins. 1996. Linkages between riparian forest composition and shredder voltinism. Arch. Hydrobiol. 137:39-58. Merritt. R.W, K.W. Cummins, and M. B. Berg. (eds.). 2008. An introduction to the aquatic insects of North America (4<sup>th</sup> edition). Kendall/Hunt, Dubuque, IA 1158p. . Petersen, R.C. and K.W. Cummins. 1974. Leaf processing in a woodland stream. Freshwat. Biol. 4: 343-368.]

146 2965 ...richness... Is this species richness? It would be more likely density.

146 2966-67 This is a basic tenet of the River Continuum Concept.

147 2977 ...filterers (macroinvertebrates ...suspended FPOM)... Citation? See 146, 2970.

148 3016-17 Again, it should be made clear that “richness” is taxa richness.

161 3270 [A note.] This section makes one wonder if the organization of the report should have been by ecoregion, with the four aquatic system types as subheadings under each because the discussion of each of the four is so driven by ecoregion setting.

177 3622 ...length of the riparian area... This is ambiguous? Portion of the stream length that is bordered by riparian vegetation, or should this actually be width?

178 3650 ...productivity of *vascular* plants and algae...

- 179 3661 stream shading...be beneficial to fish and biota... Cooler temperatures beneficial to (non-fish) biota? According to Q10 relationships, cooler temperatures would slow production of invertebrates. How would the slowing of production of potential prey for fish be beneficial for fish?
- 179 3663 ...is used... used by managers?
- 181 3707 This sentence is too vague. What is being managed? The forest, fish, bank erosion, etc.?
- 181 3719 This may not be the place to address this, but many riparian corridors are dominated by shrubby or tree (red) alders that are nitrogen fixers and constitute a major source of nitrogen.

### Additional Comments Submitted by Dr. Walter K. Dodds

The meeting confirmed that the document is well written and makes the case for connection to downstream waters for most wetlands and all streams.

In general, I left this meeting with the idea intact that connection of small streams to rivers is important biologically, chemically and physically. Furthermore, in aggregate, many small streams act to define the characteristics of the watershed and influences on the streams and rivers below. This is true for nutrients (adequately supported in document) and organisms (e.g., Fagan 2002).

The section on streams should include ideas from the literature on subsidies and feedbacks. For example marine derived nutrients from spawning salmon can influence small streams, but this material also moves down to larger rivers. There is substantial literature on this idea; the report could start with the book on this issue by Polis et.al. (2004).

Wetlands are clearly connected to downstream waters. Several more references could be put in related to this idea (Devito et al., 1999, Richardson et al., 2004, McCormick et al., 2006, Strauss et al., 2009). Biological connections can also move nutrients among isolated water bodies (e.g., Manny et al., 1994, Post et al., 1998).

Some wetlands have very clear and fast connections to downstream waters, particularly those in more permeable unconsolidated sediments or karst areas (e.g., Malard et al., 1994, White et al., 1995).

Fagan, W.F. (2002) Connectivity, fragmentation, and extinction risk in dendritic metapopulations. *Ecology*, **83**, 3243-3249.

Devito, K.J., Hill, A.R. & Dillon, P. (1999) Episodic sulphate export from wetlands in acidified headwater catchments: prediction at the landscape scale. *Biogeochemistry*, **44**, 187-203.

Manny, B.A., W. C. Johnson and R. G. Wetzel. (1994) Nutrient additions by waterfowl to lakes and reservoirs: predicting their effects on productivity and water quality. In: *Hydrobiologia* 279/280:121-132. (Ed^Eds.

Mccormick, P.V., Shuford, R.B.E. & Chimney, M.J. (2006) Periphyton as a potential phosphorus sink in the Everglades Nutrient Removal Project. *Ecological Engineering*, **27**, 279-289.

Polis, G.A., Power, M.E. & Huxel, G.R. (2004) *Food webs at the landscape level*, University of Chicago Press.

Post, D.M., Taylor, J.P., Kitchell, F.J., Olson, M.H., Schindler, D.E. & Herwig, B.R. (1998) The role of migratory waterfowl as nutrient vectors in a managed wetland. *Conservation Biology*, **12**, 910-920.

Richardson, W.B., Strauss, E.A., Bartsch, L.A., Monroe, E.M., Cavanaugh, J.C., Vingum, L. & Soballe, D.M. (2004) Denitrification in the Upper Mississippi River: rates, controls, and contribution to nitrate flux. *Canadian Journal of Fisheries and Aquatic Sciences*, **61**, 1102-1112.

Strauss, E.A., Richardson, W.B., Cavanaugh, J.C., Bartsch, L.A., Kreiling, R.M. & Standorf, A.J. (2009) Variability and regulation of denitrification in an Upper Mississippi River backwater.

- Malard, F., J.-L. Reygrobellet, J. Gibert, R. Chapuis, C. Drogue, T. Winiarsky and Y. Bouvet. (1994) Sensitivity of underground karst ecosystems to human perturbation - conceptual and methodological framework applied to the experimental site of Terrieu (Herauld- France). In: *Verh. Internat. Verein. Limnol.* 25:1414-1419. (Ed^Eds.)
- White, W.B., D. C. Culver, J. S. Herman, T. C. Kane and J. E. Mylroie. (1995) Karst Lands. In: *Am. Sci.* 83:451-459. (Ed^Eds.)

## **Additional Comments Submitted by James W. La Baugh**

### **Post meeting comments**

In Reference to Charge Question Number 3, I offer the following text as one possible solution to the dilemma posed by use of the term non-riparian and channel origin wetlands.

EPA connectivity panel - wetland classification note and suggestion

One document that discusses various aspects of wetlands in relation to hydrological characteristics is

Winter, T.C., and Woo, M-K. 1990. Hydrology of lakes and wetlands, p. 159-187, in Wolman, M.G., and Riggs, H.C., (eds.) Surface Water Hydrology. The Geology of North America, volume O-1. Geological Society of America, Boulder, Colorado.

In this document the authors note that existing classifications are not easily unified. In Winter and Woo (1990), a variety of lakes and wetlands were examined in the context of geologic settings, hydrologic processes controlling water balances, and physiographic settings.

In the EPA connectivity draft, the need to define channel origin wetlands is not compelling. If channel origin wetlands were simply thought of in terms of being the headwaters of a river, the need to include them as a separate category is eliminated. They would fall into the category of being associated with a river. The result would be two classes of wetlands, those associated directly with rivers, riverine wetlands (borrowing from Winter and Woo) - river headwater, riparian, and floodplain wetlands ? and those not directly associated with rivers, non-riverine wetlands. Use of these two simple terms, riverine and non-riverine wetlands, also makes a distinction among wetlands: the first, those wetlands more likely to be directly connected by a surface water connection with a river, and second, those wetlands less likely or unlikely to be directly connected by a surface water connection with a river. I suggest you substitute river headwater wetlands for channel origin wetlands in the text and include them in text pertaining to riparian and floodplain wetlands. Then substitute non-riverine wetlands for non-riparian wetlands throughout the document. Such revision might solve the wetlands classification dilemma discussed on January 30, 2012 during the panel meeting.

As an aside, Plate 2 from Winter and Woo (1990) is a nice portrayal of the fact that about half of North America is not humid. A figure for the lower 48 states derived from that plate is Figure 14, page 21 in

Reilly, T.E., Dennehy, K.F., Alley, W.M., and Cunningham, W.L., 2008. Ground-Water Availability in the United States. U.S. Geological Survey Circular 1323, 70 p. <http://pubs.usgs.gov/circ/1323/>

although the figure in Reilly et al. (2008) does not feature the gradients within the semi-arid to arid region shown in the plate of Winter and Woo (1990).

### **Comment on organization of the document:**

It would be useful to consider reorganization of the document. Conceptual framework material regarding connectivity and influence appearing in both the stream (section 4) and wetlands (section 5) sections could be

moved to section 3 (A conceptual framework) for consistency and clarity of presentation. Readers could then be referred to aspects of this common framework as needed in subsequent discussion of the relation of streams and wetlands to rivers.

One way of organizing a synthesis document is to present the conceptual framework as the main body of the text, with examples from different settings shown as ‘boxes’ or ‘sidebars’ – see Winter et al. (1998) as an example - <http://pubs.usgs.gov/circ/circ1139/> [this reference is cited in the current version of the document]. Another way of organizing a synthesis document is to present the conceptual framework as the main text, using ‘boxes’ interspersed to highlight particular technical nuances, with case studies as part of the text appearing after presentation of the conceptual framework – see Healy et al. (2007) as an example - <http://pubs.usgs.gov/circ/2007/1308/>

Comment regarding the definition of groundwater in the glossary:

The definition is correct. One of the other reviewers suggested labeling all subsurface as groundwater. Water in the unsaturated zone is not groundwater. See also page 4 of Heath, R.C., 1983, Basic ground-water hydrology U.S. Geological Survey Water Supply Paper 2220, 84 p.  
<http://pubs.usgs.gov/wsp/wsp2220/>

Comment regarding use of the term watershed:

The document never clearly states that the term watershed as used in the report refers to surface water watersheds. It would be useful to note this convention when the word is first used. I may have missed something, but did not find groundwater watersheds mentioned in the text. Somewhere in the introduction, readers would benefit from a brief statement that groundwater watersheds also exist but might not coincide with surface water watersheds. Furthermore the boundaries of those watersheds can change over time in response to changing hydrologic conditions. This subject may fit in when the concept of groundwater flow systems is introduced. As noted in my first comment regarding question 1. Figure 3-5 is inaccurate in its portrayal of local, intermediate, and regional flow systems. It would be better to use Toth's figure to do that. A local flow system is one in which groundwater flows from a water table high to an adjacent lowland. An intermediate flow system is one in which groundwater flows from a water table high to a lowland that is not immediately adjacent to the water table high. If the depth to width ratio of the aquifer is large enough, a regional flow system may also be present. Topographic divides do not always coincide with water table highs. Variability in the presence or absence of coincidence of surface water and groundwater watersheds is documented in Winter, T.C., Rosenberry, D.O., and LaBaugh, J.W., 2003, Where does the ground water in small watersheds come from? Ground Water, volume 47, number 7, pages 989-1000.

Comment about illustration of hydrologic landscapes of the continental United States and Alaska and Hawaii:

Mention was made during the discussion that it might be useful to provide readers with the spatial context of ecoregions and hydrologic landscapes. Figure 8 on page S79 of Wollock et al., 2004 cited in the EPA document is the one that was suggested. It is also possible that inclusion of this figure, as well as the text needed to explain the content of the figure, might distract from the main focus of the conceptual framework because of the detail involved.

Comment about illustrating effects of pumping on groundwater flow paths interacting with a stream:

Figure C-1 on page 15 of Winter et al. (1998) shows effect of a pumping well on changes in groundwater flow paths.

Note about example illustrations

Sources of hydrologic processes or connections (flow path) illustrations are provided herein. These are provided simply as examples of ways flow processes or connections have been illustrated in a variety of settings apart from the more general diagrams used from the Winter et al. (1998) reference in the EPA connectivity document.

[Note: the following two references are key citations for Florida wetlands that were not included in the EPA document, but should be. Essential references]

[Essential reference] Haag, K.H., and Lee, T.M., 2010, Hydrology and ecology of freshwater wetlands in central Florida – A primer. U.S. Geological Survey Circular 1342, 138 p.  
<http://pubs.usgs.gov/circ/1342> [Figure B-1, page 17 – flow in relation to seepage wetlands; Figure 5, page 21 – flow in Florida karst terrane]

[Essential reference] Lee, T.M., Haag, K.H., Metz, P.A., and Sacks, L.A., 2009, Comparative Hydrology, Water Quality, and Ecology of Selected Natural and Augmented Freshwater Wetlands in West-Central Florida. U.S. Geological Survey Professional Paper 1758, 152 p.  
<http://pubs.usgs.gov/pp/1758/>  
[Figure 1, page 4 – water budget of isolated wetland with fluctuating water level; Figure 11, page 24 – example of flow system in relation to wetland]

Buszka, P.M., Cohen, D.A., Lampe, D.C., and Pavlovic, N.B., 2011, Relation of Hydrologic Processes to Groundwater and Surface-Water Levels and Flow Directions in a Dune-Beach Complex at Indiana Dunes National Lakeshore and Beverly Shores, Indiana. U.S. Geological Survey Scientific Investigations Report 2011-5073, 75 p.  
<http://pubs.usgs.gov/sir/2011/5073/>  
[Figure 3, page 5 – Effect of tile drain on flow]

[Essential reference] Tribble, Gordon, 2008, Ground Water on Tropical Pacific Islands—Understanding a Vital Resource. U.S. Geological Survey Circular 1312, 35 p.  
<http://pubs.usgs.gov/circ/1312>  
[Page 4 – Figure showing surface and groundwater flow paths; Pages 10 and 11 - various groundwater flow settings ]

Faunt, C. C., editor, 2009, Groundwater availability of the Central Valley Aquifer, California. U.S. Geological Survey Professional Paper 1766, 225 p.  
<http://pubs.usgs.gov/pp/1766>  
[Figure A9, upper part, page 21 – surface and groundwater flow paths in the Sacramento Valley]

Barlow, P.M., 2003, Ground Water in Freshwater-Saltwater Environments of the Atlantic coast. U.S. Geological Survey Circular 1262, 113 p.

<http://pubs.usgs.gov/circ/2003/circ1262/>

[Figure 3, page 4 – Surface water and groundwater flow paths in the Atlantic coastal plain]

Izbicki, J.A., Johnson, R.U., Kulongoski, J., and Predmore, S., 2007, Ground-Water Recharge from Small Intermittent Streams in the Western Mojave Desert, California. Chapter G in Stonestrom, D.A., Constantz, J., Ferré, T.P.A. and Leake, S.A., editors, 2007, Ground-Water Recharge in the Arid and Semiarid Southwestern United States. U.S. Geological Survey Professional Paper 1703 <http://pubs.usgs.gov/pp/pp1703/>

The entire report is a large document so chapter link is provided below.

<http://pubs.usgs.gov/pp/pp1703/g/pp1703g.pdf>

[Figure 4, page 163 – hydrologic features of intermittent streams in the Mojave Desert]

Planert, M., and Williams, J.S., 1995, Ground Water Atlas of the United States - California, Nevada. U.S. Geological Survey Hydrological Atlas 730-B,

[http://pubs.usgs.gov/ha/ha730/ch\\_b/gif/b025.gif](http://pubs.usgs.gov/ha/ha730/ch_b/gif/b025.gif)

(Also available as an Adobe Illustrator eps file)

[Figure 25 – block diagram of basin types showing groundwater flow relations to types of playas]

\* Documents referred to in general discussion, but not critical for the EPA document, except where noted:

Document related to the fact the concept of average conditions is outdated:

[Milly, P.C.](#), J Betancourt, M Falkenmark, R M Hirsch, Z W Kundzewicz, D Lettenmaier, and [Ronald J Stouffer](#), 2008: **Stationarity is dead: Whither water management?** *Science*, **319(5863)**, 573-574.

Document related to conceptual framework of geomorphology in relation to milldam:

Merritts, Dorothy, Rahnis, Michael, Walter, Robert, Hartranft, Jeff, Cox, Scott, Scheid, Chris\*, Potter, Noel\*, Jenschke, Matthew\*, Reed, Austin\*, Matuszewski, Derek\*, Kratz, Laura\*, Manion, Lauren\*, Shilling, Andrea\*, Datin, Katherine\*, 2011 (in press), The rise and fall of Mid-Atlantic streams: Millpond sedimentation, milldam breaching, channel incision, and stream bank erosion: Reviews in Engineering Geology, special issue on “The Challenges of Dam Removal and River Restorations”, editors Jerome V. DeGraff and James E. Evans.

Document related to hydrological and biological interrelations pertaining to removal of invasive species from riparian zones:

Shafroth, P.B., Brown, C. A., and Merritt, D.M., editors, 2009, Saltcedar and Russian Olive Control Demonstration Act Science Assessment. U.S. Geological Survey Scientific Investigations Report, 2009-5247, 143 p.

<http://pubs.usgs.gov/sir/2009/5247/>

Document pertaining to analysis of changing hydrologic conditions in relation to potential for Devils Lake to spill to a river:

Vecchia, A.V., 2008, Climate simulation and flood risk analysis for 2008-40 for Devils Lake, North Dakota: U.S. Geological Survey Scientific Investigations Report 2008-5011, 28 p.  
<http://pubs.er.usgs.gov/usgspubs/sir/sir20085011>.

Document that discusses the relation of hydraulic conductivity to presence/absence of groundwater watershed divides:

Winter and LaBaugh (2003) cited in the EPA document. The source of the information regarding the importance of moderate to highly permeable versus poorly permeable geologic substrates is Haitjema, H.M., 1995. Analytic element modeling of groundwater flow. Academic Press, San Diego, California.

Documents pertaining to overviews of wetlands in the Nebraska Sandhills:

[Essential reference] Novacek, J.M., 1989, The water and wetland resources of the Nebraska Sandhills, in van der Valk, A., ed. Northern Prairie Wetlands, Iowa State University Press, Ames, Iowa, p. 340-384.

Gosselin, D.C., 1997, Major-ion chemistry of compositionally diverse lakes, Western Nebraska. U.S.A.: implications for paleoclimatic interpretations, *Journal of Paleolimnology*, 17:33-49.

Document related to presence and characterization of playas:

[Essential reference] Wood, W.W., 2002, Role of ground water in geomorphology, geology, and paleoclimate of the southern High Plains, USA: *Ground Water*, v. 40, p. 438-447.

Document providing details about the dynamic nature of hydrological and biological interactions of prairie wetlands:

Winter, T.C., ed., 2003, Hydrological, chemical, and biological characteristics of a prairie pothole wetland complex under highly variable climate conditions – The Cottonwood Lake area, east-central North Dakota: U.S. Geological Survey Professional Paper 1675, 109 p.  
<http://pubs.usgs.gov/pp/1675/report.pdf>

Document related to movement of nutrient plume from infiltration ponds to nearby lake:

McCobb et al., 2003, Phosphorus in a Ground-Water Contaminant Plume Discharging to Ashumet Pond, Cape Cod, Massachusetts, 1999. U.S. Geological Survey Water-Resources Investigations Report 02-4306, 69 p.  
<http://pubs.usgs.gov/wri/wri024306/>

Document related to irrigation canal recharge of groundwater as source of baseflow in rivers  
inhabited by endangered fish species:

Ely, D.M., 2003, Precipitation-Runoff Simulations of Current and Natural Streamflow Conditions in the Methow River Basin, Washington. U.S. Geological Survey Water-Resources Investigations Report 03-4246, 43 p.

<http://pubs.usgs.gov/wri/wri034246/>

## **Additional Comments Submitted by Dr. Mark C. Rains**

### **REVIEWER COMMENTS ON CONCEPTUAL FRAMEWORK:**

#### **SUMMARY**

The key flaw in the document is that you arbitrarily break the landscape into three components, make the focus of the document on the individual discussions of those three components, and therefore make it difficult for you to show the inherent connectivity across these components. To counter this, I think that you should make the conceptual framework the highest order of organization in this document. The conceptual framework should be the central point of the document—the rest of the document should be to support and better explain this conceptual framework. Then conceptual framework should start with the premise that all components of the landscape are connected, and that what differs is the degree to which they are connected and the importance of those connections to downstream systems. You should clearly explain hydrological, chemical, and biological connectivity—but especially hydrological connectivity—in the context of the relevant literature (e.g., Pringle 2001, Pringle 2003a, Pringle 2003b, Freeman et al., 2007), using clear diagrams to illustrate that connectivity extends from ridges to reefs and connects all of the individual elements discussed in the document. You also should clearly explain the broader conceptual framework that you build relating to the five functions or roles that wetlands and streams play (e.g., source, sink, etc.). Last, you should explain how this landscape-scale connectivity means that the cumulative effects of many wetlands and streams can be large, even if the individual effect of one wetland or stream may be small. This, then, should be the foundation to which you return throughout the document, always reminding the reader about how the supporting information in each of the three individual components relates to this conceptual model, and showing specifically how connections and their downstream effects are clear in some cases and not so much in others.

#### **DETAILED COMMENTS**

General Comment: Throughout the document, there were terminology problems that make the basic conceptual framework and the scientific evidence difficult to follow. The first problem relates to the various uses of the terms headwaters, headwater streams, and streams. These are often used interchangeably, even though they are not commonly used interchangeably, and are not defined as such in the Glossary. To improve clarity, the standard definitions in the Glossary should be used throughout the text. The second problem relates to the use of connectivity. At times, it is used independently; at other times, it is used following a specific modifier (e.g., biological connectivity). This would not be a problem if independent usage implied any or all kinds of connectivity. However, that doesn't seem to be the case; rather, independent usage often seems to imply hydrological connectivity, and perhaps even surface-water connectivity (e.g., l. 594-597). To improve clarity, independent usage should refer to the existence of any kind of connectivity, while modified usage should refer to the existence of a specific kind of connectivity.

General Comment: There are significant problems with some of the technical aspects of the conceptual framework, particularly in relation to how water gets from uplands to wetlands or streams or between wetlands and streams. This is a critical part of the conceptual model, because it underlies the complex

pathways and controls on hydrological connectivity. Lacking a proper conceptual framework in this regard, the document will fail to make a strong case not only for hydrological connectivity but also for all types of connectivity at spatial and temporal scales that matter in a regulatory environment. I make numerous specific comments in relation to this below.

l. 522-523: Rains et al. (2006, 2008) would be good references for this condition.

l. 534-536: This sentence concludes that water flows “downhill”. This isn’t actually true. Water flows downgradient, where gradient is primarily due to differences in elevation (i.e., the downhill part of downgradient) and pressure. Pressure plays important roles in surface-water flows, but plays even more important roles in groundwater flows, including groundwater flows as they relate to the conceptual framework and the scientific evidence presented throughout each of the subsequent chapters.

l. 575-577: This is not the correct federal definition of a wetland. The federal definition of a wetland is a regulation—which carries the full force of law—that can be found at 33 CFR 328.3(b): “The term ‘wetlands’ means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.” This is very similar to a definition used later in the document (l. 3455-3456). What the authors refer to here is the Corps of Engineers Wetlands Delineation Manual (USACE 1987), which is guidance—which does not carry the full force of the law—on how to delineate a wetland and not a regulation—which does carry the full force of the law—on how a wetland is defined. One benefit of using the correct federal definition of a wetland found at 33 CFR 328.3(b)—which is more generic and inclusive, with rather vague boundaries—is that you won’t struggle so much in trying to explain what you are considering a wetland in the riparian and floodplain wetland discussion (l. 3531-3540).

l. 613-614: There are two primary types of aquifers: unconfined and confined. In unconfined aquifers, the upper surface of the saturated zone is defined by the water table; in confined aquifers, the upper surface of the saturated zone is defined by the confining layer, and the water in the saturated zone is under pressure and will rise up to the potentiometric surface if the confining layer is perforated (e.g., by a piezometer or even by a natural fracture, as occurs at many springs). See my comment titled “Figure 3-4”, below.

l. 614-615: This is an inadequate definition of groundwater, because it leaves the issue of water in the unsaturated zone undefined. I suggest that you define groundwater as all water underground, be it in the unsaturated or saturated zones, then distinguish between the two when necessary by referring to them specifically as unsaturated-zone (or vadose-zone) groundwater and saturated-zone groundwater, respectively.

l. 615-616: There are many saturated deposits that we do not commonly call aquifers. Clays, for example, are commonly saturated but are not commonly called aquifers, and are instead commonly called aquitards, perching layers, or confining layers, depending upon the role they are playing. Perhaps you mean highly permeable instead of just permeable, but if so then you chose poor examples as soil could be anything, including low-permeability clay-rich soils, and rock has extremely low primary permeability, though it can have relatively high secondary permeability if there are abundant and well-connected fractures. You might instead say: “Relatively highly permeable materials (e.g., sand and gravel) that are saturated and in which groundwater is stored and transmitted are referred to as aquifers.”

Figure 3-4: This is an oversimplification that affects your conceptual framework. I suggest that you show both unconfined and confined aquifers here. I know that this is a bit confusing, but is critically important in understanding connectivity. Many waters are hydrologically connected by unconfined aquifers, but many others are hydrologically connected by confined aquifers, especially where confined aquifers are perforated and regional groundwater discharges to streams and rivers (e.g., Kish et al., 2010) or surface water recharges regional groundwater (e.g., Sinclair 1977).

l. 628-630: Kish et al. (2010) would a good reference at the end of the last clause as they showed that the vast majority of flow in the Hillsborough River, west-central Florida, was groundwater discharged from the Floridan aquifer, primarily at a single spring.

l. 631-648, Figure 3-5: I've lumped the text and figure here, because they are so closely related.

There are quite a few things wrong here, which stem from an oversimplification on the part of Winter et al. (1998), which is the referenced paper but not the original work, and a misinterpretation on the part of these authors. The original work, cited in Winter et al. (1998), was by Toth (1963). Haitjema and Mitchell-Bruker (2005)—who, incidentally, were students of Toth's—showed that Toth (1963) was correct, but only for certain cases such as the special case in which he was working. The truth is somewhat more complicated, and relates to important controls by climate and geology, especially geologic heterogeneity. Still, you might decide to keep this, subject to some comments below, because there's nothing really wrong with using terms like local and regional groundwater flows. (Although I must admit that I've never understood the distinction between intermediate and regional groundwater flows.) If you do, however, you need to revise Figure 3-5, which is incorrect. Local groundwater flows are from a local high to a local low. This is the case in Figure 3-5. However, intermediate and regional groundwater flows are larger in spatial scale and cross one or more groundwater divides (i.e., they cross under one or more potential local groundwater flows). This is not the case in Figure 3-5; the intermediate groundwater flow is from a local high to a local low (i.e., it's another local groundwater flow) while the origin of the regional groundwater flow is a bit unclear.

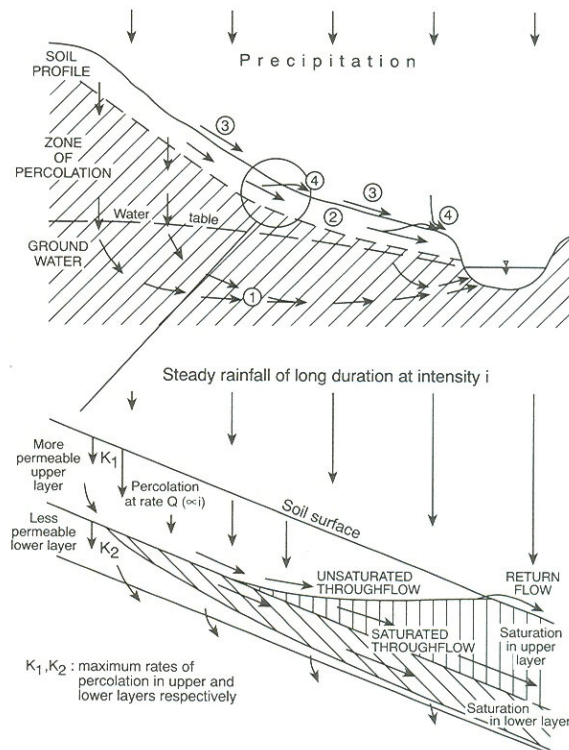
Regardless, I think that this is an incomplete conceptual model of flow from uplands to rivers and wetlands. There actually are four pathways that water can take from an upland to a river or wetland (Figure 1; Knighton 1998).

- Saturated Groundwater Flow (Pathway 1 in Figure 1): This is common flow of groundwater through the saturated zone. In this case, this would be an example of a local groundwater flow, though in other cases these might be intermediate or regional groundwater flows.
- Throughflow (Pathway 2 in Figure 1): This is quick flow through the unsaturated zone. This is commonly rapid flow through preferential flow paths, which can be soil cracks, animal burrows, or naturally formed soil pipes.
- Infiltration-Excess Overland Flow, or Hortonian Overland Flow (Pathway 3 in Figure 1): This is overland flow where there is an unsaturated zone between the overland flow and the water table. This occurs when the rainfall rate exceeds the infiltration rate, a thin layer of saturation blankets the surface, and excess rainfall runs off.

- Saturated Overland Flow, or Dunne's Mechanism of Overland Flow (Pathway 4 in Figure 1): This is overland flow where the water table has risen to the surface and subsurface storage is full. This area varies through the course of the year and a given storm, giving rise to the term variable source area.

This is a more complete and technically correct conceptual model on which to base your reasoning. This is particularly true, because this emphasizes an important point, which I don't think comes through in the document, which is that headwaters continue from the headwater stream up to the summit of the adjacent hillslope. Headwater streams and adjacent hillslopes are, in fact, integrally connected, to the extent that headwater streams cannot exist absent the adjacent hillslopes. This point is central to the argument made by Nadeau and Rains (2007), and can be seen (explicitly, in some cases) in the way that they discuss the references therein. (See, specifically, the way they discuss Triska et al., [2007] and Meyer et al., [2007], though both are referred to not as "2007" but, rather, as "this issue".)

l. 676-679: Your definition of alluvium is somewhat confusing, in that there is a separate item in the list that comprises "at the base of a mountain", which could be either an alluvial fan (i.e., a fan of deposits deposited by water flowing off of a hillslope and into a valley) or a colluvial fan (i.e., a fan of deposits deposited by gravity pulling dry materials down a steep hillslope).



**Figure 1. This is copied from Knighton (1998). The text above refers to this figure.**

l. 720-722: You might follow this with a specific example. For example, wetlands can be seasonally isolated, connected by groundwater flows, and connected by surface-water and groundwater flows (Rains et al., 2006, 2008).

- l. 794-796: A good reference for the first three items in this list would be Hammersmark et al. (2008); a good reference for the fourth and last item on this list would be Wolman and Miller (1960).
- l. 896-899: A stream or wetland also can provide different functions at the same time, depending upon perspective. Rains et al. (2006) showed evidence that vernal pools simultaneously serve as a sink for nitrogen and a source for organic carbon, because nitrogen-rich/organic carbon-poor groundwater flows into vernal pools, the nitrogen is uptaken and converted to organic carbon, and nitrogen-poor and organic carbon-rich surface water and groundwater flow out of the vernal pools.
- l. 990-993: The parenthetical list of “internal components” includes “alluvium” and “geologic materials”, but alluvium is a geologic material. I suggest omitting “geologic materials”.
- l. 1016-1018: Water-borne contaminants can still be transported from a closed-basin depression to a river through groundwater flow.
- l. 1053-1055: Rains et al. (2006, 2008) would be good references for this condition.
- l. 1056-1059: You might also mention that downstream transport of seeds and/or propagules and seasonal flooding of riparian/floodplain wetlands is essential for the recruitment of vegetation, especially willows and cottonwoods (McBride and Strahan 1984, Scott et al., 1996, Mahoney and Rood 1998).
- l. 1079-1222: I think that this entire discussion could be improved if it were integrated to include both climate and watershed characteristics at the same time, using Winter (2001) and Wolock et al. (2004) as the basis for the discussion. This is especially apparent when you compare the different the different hydrographs, which you try to do only in the context of climate, but are, in fact, the result of climate operating on watershed characteristics, an inconvenient fact that you end up having to mention briefly in l. 1134-1135.
- l. 1080-1081: I don’t think that this statement is technically true, given the importance of geology, topography, and land cover. It’s probably better to say that “Climate determines the amount, timing, and duration of water available to the watershed.”
- l. 1092-1093: How are you defining water surplus? Is it precipitation minus evapotranspiration? If so, then this sentence isn’t always true because the highest water surplus in snowy catchments is in mid-winter, when snowfall is greatest and evapotranspiration is negligible, but flow is low because most of the water is locked up in the snowpack storage.
- l. 1098-1104: The first clause in the first sentence is only half true. See the descriptions of the two types of overland flow in my comment titled “l. 631-648, Figure 3-5” above. Because you start with only a half true premise, your subsequent examples are not altogether true. For example, overland flows can occur simply where water tables are shallow, regardless of rainfall intensities.
- l. 1194-1200, Figure 3-17: I’ve lumped the text and figure here, because they are so closely related. The paragraph uses incorrect terminology. See my comment titled “l. 615-616” above. There isn’t such a thing as an “impermeable aquifer”, because an aquifer must be able to store and transmit water, by definition, and a deposit that is impermeable cannot do either, also by definition. Similarly, all aquifers are permeable, so the

term “permeable aquifer” is redundant. Also, permeability is just one part of what controls the direction and rate of groundwater flow. Hydraulic head is the other part. Therefore, the entire discussion here about how permeability controls the direction of groundwater flow is not entirely correct. However, the general themes in the paragraph and in the figure are not entirely incorrect, except for the incorrect terminology in both the paragraph and the figure legend and explanation. Therefore, I think this can all be rescued, if the terminology is corrected and the controls on the direction and rate of groundwater flow are better explained. This can all be done better if you adopt the more complete and technically correct conceptual model I suggest in my comment titled “l. 631-648, Figure 3-5”.

l. 1223-1318: This is a bit of awkward section because distribution is equally controlled by climate and geology, so this isn’t really a standalone factor equal in importance to climate and watershed characteristics. You should probably state as much at the start, and could readily reference Tihansky (1999) as an example, as she shows that climate and geology control the distribution of sinkhole depressions in Florida, most of which are wetlands or lakes, particularly concentrating them in west-central Florida.

l. 1274-1278: This is not exactly true. Floodplains typically don’t flood uniformly laterally away from the channel; rather, floodplains typically flood by engaging secondary and other paleochannels, sometimes by groundwater upwelling, other times by overbank flow (Tockner et al., 2000). These secondary and other paleochannels are all over the floodplain, and can be at the extreme edge of the floodplain complex, and the effect is that riparian/floodplain wetlands do not connect strictly as a function of distance from the main channel.

l. 1408-1413: Another excellent example is Hammersmark et al. (2008), who showed that the restoration of rivers, where incised channels are backfilled and the historic channels are reoccupied on the historic floodplains, can decrease the duration of dry season baseflow by (a) raising the alluvial water table and therefore increasing losses to evapotranspiration and (b) decreasing the hydraulic gradient and therefore the flux of water from the alluvial aquifer to the channel.

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## **Additional Comments Submitted by Dr. John S. Richardson**

### **Post-meeting comments**

It seems that there is a need to go beyond connectivity, to include aspects of the effects downstream. This was made clearer during the meeting. It also clarified why there were sections of the charge questions that seemed more about the aggregate effects downstream, particularly question #4. This topic is not well covered in the report, and a separate section on downstream effects would be warranted. The connectivity aspects do not try to address the magnitudes of effect sizes. Along with the discussion of effects, the nature of those effects, and especially cumulative effects, needs to be elaborated. After the fact, I realized that the title “Connectivity...” in the report and all the workshop documentation led me to focus on the connections and not the effects. Given that the 1<sup>st</sup>, 2<sup>nd</sup> and 4<sup>th</sup> charge questions seem to be about consequences downstream, perhaps that should be better reflected in the title. It would certainly have drawn our attention more specifically to the quantification of effects.

As discussed in the meeting on the 30<sup>th</sup> January, the confusion over floodplain versus riparian needs to be clarified. Likewise, the category of non-floodplain wetlands needs more refinement as it covers an enormous range of wetland types. I think that if “floodplain” equals “riparian” in this scheme, then the use of floodplain should suffice. I found the use of “riparian” was not in line with what I consider to be riparian, but then it needs defining either way.

The executive summary needs to be shortened. As currently written it is rather long. I cannot determine who would read such a long summary. I know the document is intended for a broad readership, but perhaps a single page for the executive summary, and then the synthesis in the end of the document might cover all the rest of what is currently in the executive summary.

A brief section outlining uncertainties would be helpful. Perhaps that could go into an expanded chapter 6. This could provide a useful focal point for research to be done, or simply to provide an alert as to what we have less confidence in saying as a scientific community. It is reasonable to acknowledge that there remain uncertainties around the science.

The final section should be a synthesis and have some declarative statements, such as are included in the charge questions. The current 6 pages of chapter 6 seems insufficient compared to the enormous detail of the remainder of the document.

Here are some additional references, from those that address spatially structured populations of amphibians in wetlands, to papers about effects from streams to estuaries, resource subsidies, and large-scale transformations of carbon along freshwater networks. The Naiman et al. (2000) reference includes the curves from the FEMAT (1993) exercise showing how different functions link up riparian areas with water.

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## **Additional Comments Submitted by Dr. Joel W. Snodgrass**

### **Minor notes and typos**

Lines 794-794: should also include connection of floodplain wetlands to each other as a critical function of overbank flow. Many species are found associated only with floodplain wetlands and depend on overbank flows to connect floodplain wetlands for dispersal.

Line 826: delete “has”—should be “This water can alter geomorphology...”

Line 900: replace colon with period.

Line 998: add “is”—should be “...the entire river system is difficult.”

Lines 1445-1453: this paragraph describes a study, but does not report the findings, leaving the reader wondering about the importance of the study.

Lines 1458-1459: given the sheer number of potholes and other types of geographically isolated wetlands it is unlikely we will ever know conditions at even a moderate fraction of these systems. Does this mean we cannot draw any conclusions regarding these systems?

Line 1646: no paragraph needed here

Line 1677: delete “s” from “recharges”—should be “...ephemeral streams recharge groundwater...” Lines 2066-2067: tighten—for example, “Mulholland et al. (2008) estimated that small streams ...”

Lines 3933-3934: revise to read “... when connections between wetlands and surface waters are present.”

Lines 2347-2348: flow—“... Los Alamos Canyon resulting from untreated discharge, and less than 2% ...”

Line 7040: no volume number for this reference.

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## Post-Meeting Comments

As a general comment concerning the conceptual model introduced at the beginning of the document I think it would be a good idea to introduce both dimensions of time and space and link them to the ideas of sources, sinks, refuges, lags, and transformation. What we really have is a hill-slope to downstream river gradient where things that at the very top of a watershed (i.e., streams and wetlands) are more distantly removed from larger rivers downstream. In a sense the isolation of these headwaters and wetlands in the top of the watershed makes them sites of significant lag (e.g., water storage) and therefore potential transformation (could also be thought of as reduced spiraling length if the concept is applied to the entire gradient). Because streams and wetlands are most spatially removed from larger rivers, their individual effects will be relatively smaller and take longer periods of time to measure. However, the cumulative effect of their loss will be greater than closer streams and wetlands over the long-term. These connections between scales of time, space and the impacts of disturbance are discussed extensively in Delcourt et al. (1983). The development of the conceptual model in this way would allow the logical extension of the review to include the arguments presented earlier on the impacts of impervious surfaces and agricultural land conversion discussed in my original comments.

On a related note to the development of the conceptual view, some changes to table 3-1 would help with clarity. I do like the idea of not having a specific sequence of wetland, stream, and river. Yes, larger rivers are usually downstream (but may not be when rivers enter deserts), but wetlands and streams can occur in a sequence or be close to or relatively far removed from large rivers. The examples I would cite here are adventitious streams verse true headwater streams (See Osborn and Wiley's work that you currently cite) and channel wetlands along stream corridors (see Webster et al., 1996; Kratz et al., 1997; Magnuson et al., 1998; Baines et al., 2000; Riera et al., 2000; Webster et al., 2000 for an example in Wisconsin lakes, which are formed in the same way pothole wetlands are formed). Soranno et al. (1999) also argues for the connection between wetlands, lakes and streams based on water chemistry in these same systems. Despite the intentions of the authors' use of arrow in table 3-1, the arrows should be removed as they give the impression of an upstream/downstream gradient.

As far as the question concerning terminology for "geographically isolated wetlands," it might be best to focus the terminology on the hill slope-downstream river gradient. Channel origin wetlands should really be considered floodplain wetlands, as they are directly adjacent to a stream. The definition of floodplain wetlands would be those wetlands that occur on the floodplain of river systems (as defined by hydrology) or located within or directly adjacent to stream channels or lakes. By the way, the lake situation is completely ignored in the document. This group of wetlands would then include beaver ponds, channel origin wetlands, and wetlands and small lakes situated along stream channel (not necessarily acting as an origin of the channel). This would be more inclusive. Then you could have hill-slope wetlands replace the non-floodplain channel origin group. Hill-slope wetlands are wetlands that are not located directly adjacent to streams and lakes or on the floodplains of rivers. This would still be a very diverse group of wetlands with a range of connectivity, but would be much less confusing. I think the intent is to convey the idea that for some hill-slope wetlands we do know something about connectivity, but for other we do not.

Finally, Catherine Pringle's work in tropical streams provides another example of the influence of connectivity of low-land rivers to headwater streams on community production and structure, which should transfer into altered downstream influences (although I don't think here work measured this specifically). References are Pringle et al., 1993, 1999; Pringle and Blake, 1994; Pringle, 1996; Crowl et al., 2001; March et al., 2001, 2002.

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## **Additional Comments Submitted by Dr. Arnold van der Valk**

### **Some Additional Comments**

The main purpose of this report is to demonstrate the connectivity between streams and wetlands and navigable rivers. There are a large number of papers that have been published in the landscape ecology literature on connectivity and how to measure it. This literature is largely ignored in this report. A review of what is meant by connectivity and the various relevant ways in which streams and wetlands may be linked to rivers is needed. In fact, the whole report might have been more usefully organized around various kinds of linkages with chapters on surface water flows, groundwater flows, wind, and various animals vectors and their relative influences on navigable rivers. One of the major dilemmas facing the reviewers was that hydrological linkages are better studied and thus are much easier to demonstrate than biological linkages. Not surprisingly the report emphasizes hydrological connectivity. Biological linkages are often sporadic and highly species specific and are thus harder to document. Most of the focus on biological connectivity in the report is on fish movements into and out of wetlands on floodplains. Because isolated wetlands are linked to rivers primarily by biological linkages, I believe that this report seriously underestimates the connectivity between isolated wetlands and rivers. The literature on waterbird (ducks, geese, cranes, etc.) migratory and local movements, which is largely ignored in the report, is full of accounts of birds moving from wetlands to rivers and vice versa, e.g., Canvasbacks in the Mississippi River flyway. In the case study on prairie potholes, however, there is a good synthesis of the evidence for both hydrological and biological connectivity of potholes to rivers. In short, I think that a stronger case can be made that some of the wetlands in the isolated wetland category are connected to rivers.

I found the Non-Riparian and Channel Origin (NRCW) class of wetlands created in this report unnecessary and confusing. In fact, the term NRCW is never used in the Executive Summary. For the most part, this term is used a catchall for non-riparian/non-floodplain wetlands. The common denominator that supposedly justifies putting prairie potholes and other isolated wetlands in the same class as wetlands that are the headwaters for streams (channel origin wetlands) is unidirectional surface flow (P. 42, ll. 813-815). Although some isolated wetlands like prairie potholes during high water events do have temporary surface connections to each other and even to nearby streams, many do not as noted. Many headwater wetlands, however, can have water backing up into them from streams during flooding events. It would be simpler to eliminate the use of the NRCW class from the report. The problem with lumping these two types of wetlands together is illustrated on P. 206 ll. 4292-4294: "NRCWs, however, are generally farther from stream channels than riparian/floodplain wetlands, which make hydrologic connectivity much less frequent, if present at all." This statement is by definition untrue for channel origin wetlands.

Instead of the artificial NRCW class of wetlands, it would be more useful to follow the Cowardin et al. (1979) classification of wetlands which distinguishes five basic types (systems) of wetlands, only three of which are relevant in this context, (riverine, palustrine, and lacustrine). As defined by Cowardin et al. (1979), "The term SYSTEM refers here to a complex of wetlands and deepwater habitats that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors." Cowardin et al., recognize that intermittent streams are connected to perennial reaches of streams. They are treated as part of the riverine system. Lacustrine wetlands are found along the peripheries of lakes, and there is absolutely no doubt that they are connected to navigable water. What is being examined in this report is the connectivity between rivers and

various kinds of palustrine wetlands. Palustrine wetlands are bounded by uplands. There are many kinds of palustrine wetlands, and they are found “shoreward of lakes, river channels, or estuaries; on river floodplains; in isolated catchments; or on slopes.” In other words, this report should focus on the connectivity of different kinds of palustrine wetlands. This ranges from those clearly linked to rivers like palustrine wetlands on floodplains to those with much weaker linkages like palustrine wetlands in isolated catchments like many inter-mountain wetlands. In the case of palustrine wetlands that generally have no surface water connections to rivers, each major type should be treated separately (prairie potholes, California vernal pools, Carolina bays, Texas playas, etc.)

The Cowardin et al., classification systems is used by the National Wetland Inventory. Discussing the connectivity of palustrine wetlands to rivers would make it immediately obvious to readers familiar with wetlands what this report is trying to do, and it would link the report more directly to the existing wetland literature.

Five functions of streams and wetlands are recognized (P. 5, ll. 106-113). I would suggest renaming the last one, Lag, Desynchronization. A lag is an effect, not a function.

What is the relative importance of hydrological vs. biological connectivity? It is possible for some types of wetlands to have no surface water connection to streams. Given that all wetlands have hydric plants and a host of aquatic animals (invertebrates, birds, mammals, microorganisms, etc.), even hydrologically isolated wetlands are never isolated biologically. What species should count in establishing biological connectivity? In the report, all microorganisms (algae, bacteria, fungi, protozoans, etc.) are essentially ignored. Although the report does a good job in demonstrating the ubiquity of biological connectivity, it is unclear how important this type of connectivity is when compared to hydrological connectivity and what minimum criterion or threshold is required to demonstrate biological connectivity. Does demonstrating the one-time movement or dispersal of one species from a river or a stream to a hydrologically isolated wetland (or vice versa) mean that the “isolated” wetland is not really isolated? If just establishing some kind of biological linkage between a wetland and a river establishes connectivity, then there is no such thing as an isolated wetland.

When looking for linkages between “isolated” wetlands and rivers, a landscape approach is needed. One possible way to examine these linkages would be to use an HGM approach to estimate water, sediment, nutrient, etc. storage by the wetlands in a watershed and thus not entering the rivers. Potential linkages of various animal groups and wind could also be explored using this general approach. The more linkages that can be demonstrated the greater the influence of isolated wetlands in a watershed (or other comparable landscape unit) on the rivers in it.

In summary, the authors of the report focus primarily on surface water flows as the major link between rivers and streams and wetlands. This primarily unidirectional flow of water into rivers is easy to demonstrate and its importance can be quantified. The more complex and often sporadic and bidirectional linkages caused by wind and movement of organisms are noted, but their influence on navigable waters has rarely been documented. Whether such movements are essential for the persistence of some organisms in rivers is unknown. That some organisms (some waterfowl, some mammals, and some amphibians) use both rivers and isolated wetlands during their life cycles is known. As a consequence, in any landscape all bodies of water are interconnected and influence each other, but these interactions are often sporadic and asymmetrical.

## **Additional Comments Submitted by Dr. Mark S. Wipfli**

### **Marine-derived nutrient effects on stream productivity**

Discussed at the review on 30 Jan, 2012 was the topic of marine-derived nutrients, and their effects on headwater productivity in places that receive runs of anadromous fishes. It was suggested that a discussion of this topic be included in the report, and I agree that it should be included. This phenomenon is demonstrated through runs of adult Pacific salmon throughout the west coast of North America, but occurs along the east coast with Atlantic salmon, as well as runs of shad, lamprey, and other species, and throughout other parts of the world. Spawning adults deliver nutrients and carbon from the ocean when they return to fresh water to spawn (and die). This subsidy of nutrients and carbon (energy) from the ocean has been universally shown to increase stream productivity, including in headwater streams, at multiple trophic levels (periphyton, aquatic invertebrates, and fishes). The increased production in headwaters in turn provides more invertebrates that can get flushed downstream from smaller headwater channels to downstream waters. Thus, the ocean is connected to headwaters via the movement of marine subsidies into watersheds. In turn a portion of this invertebrate production can subsequently get delivered downstream from headwaters.

Here are some of my papers on this topic. They in turn contain numerous additional citations on the subject that can be included in the report, if EPA decides this is a topic worth including.

Wipfli, M.S., J.P. Hudson, J.P. Caouette, N.L. Mitchell, J.L. Lessard, R.A. Heintz, and D.T. Chaloner. 2010. Salmon carcasses increase stream productivity more than inorganic fertilizer pellets: A test on multiple trophic levels in streamside experimental channels. *Transactions of the American Fisheries Society* 139: 824-839.

Heintz, R.A., M.S. Wipfli, and J.P. Hudson. 2010. Identification of marine-derived lipids in juvenile coho salmon and aquatic insects through fatty acid analysis. *Transactions of the American Fisheries Society* 139: 840-854.

Lang, D.W., G.H. Reeves, D.D. Hall, and M.S. Wipfli. 2006. The influence of fall-spawning coho salmon (*Oncorhynchus kisutch*) on growth and production of juvenile coho salmon rearing in beaver ponds on the Copper River Delta, Alaska. *Canadian Journal of Fisheries and Aquatic Sciences* 63: 917-930.

Hicks, B.J., M.S. Wipfli, D.W. Lang, and M.E. Lang. 2005. Marine-derived nitrogen and carbon in freshwater-riparian food webs of the Copper River Delta, southcentral Alaska. *Oecologia* 144: 558-569.

Heintz, R.A., B.D. Nelson, J.P. Hudson., M. Larsen, L. Holland, and M.S. Wipfli. 2004. Marine subsidies in freshwater: Effects of salmon carcasses on the lipid class and fatty acid composition of juvenile coho salmon. *Transactions of the American Fisheries Society*. 133: 559-567.

Wipfli, M.S., J.P. Hudson, J.P. Caouette, and D.T. Chaloner. 2003. Marine subsidies in freshwater ecosystems: salmon carcasses increase the growth rates of stream-resident salmonids. *Transactions of the American Fisheries Society*. 132: 371-381.

Wipfli, M.S., J.P. Hudson, and J.P. Caouette. 1998. Influence of salmon carcasses on stream productivity: response of biofilm and benthic macroinvertebrates in southeastern Alaska, USA. *Canadian Journal of Fisheries and Aquatic Sciences*. 55: 1503-1511.

**Some additional relevant MDN papers include:**

Bilby, R. E., B. R. Fransen, P. A. Bisson, and J. K. Walter. 1998. Response of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) to the addition of salmon carcasses to two streams in southwestern Washington, USA. *Canadian Journal of Fisheries and Aquatic Sciences* 55:1909-1918.

Bilby, R. E., Fransen, B. R., Walter, J. K., Cederholm, C. J., and W. J. Scarlett. 2001. Preliminary evaluation of the use of nitrogen stable isotope ratios to establish escapement levels for Pacific salmon. *Fisheries* 26:6-14.

Claeson, S. M., J. L. Li, J. E. Compton, and P. A. Bisson. 2006. Response of nutrients, biofilm, and benthic insects to salmon carcass addition. *Canadian Journal of Fisheries and Aquatic Sciences* 63:1230-1241.

Jonsson, B., and N. Jonsson. 2003. Migratory Atlantic salmon as vectors for the transfer of energy and nutrients between freshwater and marine environments. *Freshwater Biology* 48:21-27.

Nislow, K.H., and B.E. Kynard. 2009. The role of anadromous sea lamprey in nutrient and material transport between marine and freshwater environments. *Amer. Fish Soc. Symp.* 69:485-494.

Rand, P. S., C. A. S. Hall, W. H. McDowell, N. H. Ringler, and J. G. Kennen. 1992. Factors limiting primary productivity in Lake Ontario tributaries receiving salmon migrations. *Canadian Journal of Fisheries and Aquatic Sciences* 49:2377-2385.

**Terrestrial prey subsidies**

Another topic briefly discussed for possible inclusion in the final report was the trophic linkage between headwater streams and their riparian forests, and how this linkage affects the flow of terrestrial invertebrates from headwater streams to downstream habitats. This is another avenue through which headwater streams are connected to downstream waters. Below are a few references for the report that discuss terrestrial invertebrate subsidies to streams, which in turn contain further references the authors of the EPA report can decide on their inclusion.

Allan, J. D., M. S. Wipfli, J. P. Caouette, A. Prussian, and J. Rodgers. 2003. Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. *Canadian Journal of Fisheries and Aquatic Sciences* 60:309-320.

Baxter, C. V., K. D. Fausch, M. Murakami, and P. L. Chapman. 2007. Invading rainbow trout usurp a terrestrial prey subsidy to native char and alter their behavior, growth, and abundance. *Oecologia* 153:461-470.

Baxter, C. V., K. D. Fausch, and W. C. Saunders. 2005. Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones. *Freshwater Biology* 50(2):201- 220.

- Kawaguchi, Y., and S. Nakano. 2001. Contribution of terrestrial invertebrates to the annual resource budget for salmonids in forest and grassland reaches of a headwater stream. *Freshwater Biology* 46:303-316.
- Kawaguchi, Y., S. Nakano, and Y. Taniguchi. 2003. Terrestrial invertebrate inputs determine the local abundance of stream fishes in a forested stream. *Ecology* 84(3):701-708.
- Mason, C. F., and S. M. MacDonald. 1982. The input of terrestrial invertebrates from tree canopies to a stream. *Freshwater Biology* 12:305-311.
- Nakano, S., H. Miyasaka, and N. Kuhara. 1999. Terrestrial-aquatic linkages: riparian arthropod inputs alter trophic cascades in a stream food web. *Ecology* 80(7):2435-2441.
- Richardson, J.S., Y. Zhang & L.B. Marczak. 2010. Resource subsidies across the land-freshwater interface and responses in recipient communities. *River Research and Applications* 26:55-66.
- Saunders, W. C., and K. D. Fausch. 2007. Improved grazing management increases terrestrial invertebrate inputs that feed trout in Wyoming rangeland streams. *Transactions of the American Fisheries Society* 136:1216-1230.



## **Appendix A: Individual Reviewer Comments**



**David J. Cooper, Ph.D.**  
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Dr. David J. Cooper is a Senior Research Scientist/Professor in the Department of Forest and Rangeland Stewardship, Colorado State University, Fort Collins, Colorado. His expertise is plant and vegetation ecology and hydrologic processes supporting wetland and riparian ecosystems in western North America. He also has active projects in the Andes of Peru and Bolivia, and in Slovakia and Poland in Europe. The main themes of his research are the role of hydrologic processes in shaping ecosystems, plant establishment processes, the role of herbivory and alternative states in ecosystems, characterization of vegetation types, invasion of exotic plants into riparian areas, and restoration ecology. His work supports federal agencies including National Parks, National Forests, BLM, EPA, Bureau of Reclamation, and research support comes from these and other federal agencies as well as NSF, private corporations, local governments, and non-profit agencies. In the past ten years he has published 50 articles in peer reviewed journals, with most appearing in Ecological Applications, Journal of Hydrology, Canadian Journal of Botany, River Research and Applications, Journal of Vegetation Science, Biological Invasions, Plant Ecology, Arctic Antarctic and Alpine Research, Restoration Ecology, Journal of Applied Ecology, Hydrogeology Journal, Oecologia, Environmental Management, Wetlands, Water Resources Research, Hydrological Processes, Ecosystems, Plant and Soil, Journal of Range Management, Journal of Ecology, and Soil Biology and Biogeochemistry.



**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands  
to Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Comments submitted by Dr. David J. Cooper**

**Overall Comments**

The authors of the report have done an excellent job of bringing together a huge and scattered literature. The report was difficult to read due to its length, and I find it hard to imagine that most people will use this anything other than a reference document. The literature review indicates that our knowledge of hydrologic connections between tributary streams and wetlands and waters of the U.S. is conceptual, with case studies in several portions of the U.S. but large regions, such as western mountains, and southwestern deserts, where little is known. A few things should be clarified to make this report more useful.

The report focuses on what we know. I would suggest that each section of the report must have a discussion of what is unknown or uncertainties about connections, functions, and what future research is needed to support our understand of these processes. The report gives the impression that we know most of what is needed to understand and regulate these tributaries and wetlands. I think this is only partially correct.

The temporal aspect of these jurisdictional identifications should be clarified. For example jurisdictional wetlands, under S404, must have flooding or soil saturation for a certain number of days during the growing season. One day of saturation is insufficient, but 14 days is typically sufficient. However this report does not clarify how many hours, days, or weeks per year a tributary must flow into a water of the U.S. to be considered jurisdictional. For an ephemeral stream in Arizona that is tributary to a water of the U.S. is it sufficient if this stream flows on average 1 or 2 days per year, and in some years never flows? For a non-continuous wetland how often does the surface or subsurface connection have to occur? How often do the cited ecological functions, i.e., sediment retention, have to occur? These concepts are critical to have a definitive and objective jurisdictional approach. After the panel meeting I'm still unsure how to include every single channel across the U.S. into a single framework of ecological functioning.

Methods for measuring ecological function should be reviewed and included in this report. The U.S. has spent millions of dollars supporting the Adamus methods, Wetland Evaluation Technique, HGM and other approaches that all have been extensively peer reviewed and used in the US. I include a few key references at the end of my comments. Methods such as these are critical for inclusion because any field activities would need a framework for how to evaluate function or nexus between any stream or wetland and a downstream water.

I understand the importance of identifying “similarly situated waters” as a way of extending our understanding beyond single sites. However, the geomorphic context of such sites must be carefully evaluated. This is no simple matter and no method for doing such comparisons is presented in the report.

The definitions used in this report need significant improvement. For example wetlands, riparian, floodplain, non-riparian wetland, etc. are all in need of greater clarification. I suggest not using the Cowardin et al. (1979) definition of wetland in this report. The U.S. has regulatory definitions of wetlands that should be used as

these definitions have been peer reviewed innumerable times. Riparian is more a term of art than science. The classical definition is that it includes areas adjacent to flowing water, i.e., streams. I'm not sure how floodplains differ from riparian areas, or how riparian areas are defined or bounded.

The overall report needs an ending synthesis, not summary at the end of the document.

The example provided for Southwestern streams, the San Pedro river is not a representative stream. Much attention has been paid to the San Pedro, making it the most studied stream in the SW because it is unique. It flows north from Mexico, has many perennial reaches, almost all of the river has shallow ground water, and most has well developed riparian forests. In contrast most streams in the region are ephemeral, few are intermittent and only a very few are perennial. Few have shallow ground water. I would suggest that if the San Pedro is retained, than a second example system is presented. One of our published papers (Shaw and Cooper 2008) published in the Journal of Hydrology may provide a different representative ephemeral stream baseline. I have attached this in case EPA authors wish to use this or have not seen it.

CLASSIFICATION: I think that a classification of U.S. wetlands would be helpful as a unifying theme for the document. There are many attempts to classify wetlands and regions including EPA's ecoregion concepts from Omernick et al., in its many documents. Each region has distinctive wetland types, and it would be nice to discuss each type and issues related to connectivity, and functions that effect downstream waters. In addition, the book on Wetlands of the U.S. should be published this spring/summer by University of California Press. The wetland types or chapters within could also provide a good framework for discussing issues related to connectivity, and uncertainty in connections and ecological functions. Another potential is to organize around HGM wetland types, such as depression, slope, etc. although there is great variance through the U.S. on how basin/depression wetland function.

Beavers are a key part of the biotic/hydrologic connection for streams and riparian areas throughout the northern hemisphere, and even the southern hemisphere. It would be important to mention this important driver of connections and exchange of water, materials and biota between streams and wetlands.

I also ask EPA to remove concepts suggesting that riparian areas are "transition zones". This is completely false and misleading. Riparian zones support distinctive biota, hydrological and ecological processes that distinguish them from uplands or aquatic ecosystems.

The concept of "channel origin wetlands" is quite foreign. I think that EPA's concept was that sites of ground water discharge would support wetlands that would feed into downstream waters. However, hydrologically, many wetlands are flow through, with ground water flowing in, and ground water flowing out, and no surface water other than in the wetland. This concept is important for the prairie potholes, but also anywhere else that basin wetlands are prevalent.

Many figures could use revision as listed below:

Figure 3-2, does not show ground water flow, and little of the landscape is connected to the channels.

Figure 3-7, panel a shows a stream that virtually dries up, and it's not very representative for perennial streams in most of the US.

Figure 3-6, all of these panels show a river connected via ground water inflow. Please expand these concepts to include rivers that are not connected to adjacent lands via ground water. Either they are losing, or disconnected. Same comment for Figure 3-13 and Figure 3-16.

Figure 3-5, the scale on this is very poor. For example showing a regional GW flow that is just a tad different from local or intermediate GW flows is inaccurate.

### Technical Charge Questions

1. **This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.**

- a) **Are these conclusions supported by the scientific evidence?**
- b) **Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
- c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The conclusions are supported in part. Clearly if hazardous waste is placed into an ephemeral desert stream, the material will likely flow to a water of the U.S. on some time scale, likely years to decades.

2. **This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.**

- a) **Are these conclusions supported by the scientific evidence?**
- b) **Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
- c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The report provides evidence of these connections, but what is missing is some idea of how often and how long these connections must occur each year. I would also like to see a better review of the types of channels and wetlands that occur in the U.S. and which we have sufficient evidence for these connections, and which we don't. This could be presented in a table.

3. **This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**

- a) **Are these conclusions supported by the scientific evidence?**
- b) **Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
- c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

This is correct. Documented evidence of hydrologic connections from non-connected wetlands to streams is sparse, and the conditions for such connection are poorly known. Probably the best large-scale evidence is the long-term data collected in the prairie pothole region by Winter et al. However few such studies occur in the western US.

4. **This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**

- a) **Is this conclusion supported by the scientific evidence?**
- b) **Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**
- c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The contribution of streams and wetlands on downstream waters is well known for flood water retention (the studies by Novitski 1978 in Wisconsin should be added). Denitrification has been shown in many wetlands. However few other functions have been conclusively demonstrated for many wetland types.

#### Literature Cited

Novitzki, RP. 1978. Hydrologic characteristics of Wisconsin's wetlands and their influence on floods. Pp. 377-388, in P. Greeson, J. Clark, JE Clark (eds). Wetland functions and values: the status of our understanding. Proc. National Symposium on Wetlands. Am Water Res Assoc, Minneapolis MN.

Thomas C. Winter, Judson W. Harvey, O. Lehn Franke, William M. Alley. 2008. Surface and Ground water, a single Resource. USGS Circular 1139.

Hauer, F. R., B. J. Cook, M. C. Gilbert, E. C. Clairain, Jr., and R. D. Smith. 2001. The Hydrogeomorphic Approach to Functional Assessment: A Regional Guidebook for Assessing the Functions of Riverine Floodplain Wetlands in the Northern Rocky Mountains. Special Publ. WES, USCOE, Vicksburg, MS. p.255.

Hauer, F. R., B. J. Cook, M. C. Gilbert, E. C. Clairain, Jr., and R. D. Smith. 2000. A regional guidebook: Assessing the functions of intermontane prairie pothole wetlands in the northern Rocky Mountains. Special Publ. WES, USCOE, Vicksburg, MS. p.189.

THREE papers (PDFs attached) that you might consider referencing as they present original data on hydrologic connectivity on ephemeral and intermittent streams to riparian and wetland ecosystems

Shaw, J. and D. J. Cooper. 2008. Watershed and stream reach characteristics controlling riparian vegetation in semiarid ephemeral stream networks. *Journal of Hydrology* 350:68-82.

Westbrook, C., D. J. Cooper, B. Baker. 2006. Beaver dams and floods in controlling hydrologic processes of a mountain valley. *Water Resources Research* 42: W06404, doi:10.1029/2005WR004560

Wurster, F.C., D.J. Cooper, and W.E. Sanford. 2003. Stream/aquifer interactions at Great Sand Dunes National Monument, Colorado: Influences on interdunal wetland disappearance. *Journal of Hydrology* **271**:77-100.



## **William G. Crumpton, Ph.D.**

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William Crumpton is an Associate Professor in the Department of Ecology, Evolution and Organismal Biology at Iowa State University, and Chair of ISU's Environmental Science and Environmental Studies programs. He obtained his B.S. (interdisciplinary science) and M.S. (marine science) from the University of West Florida, his Ph.D. (limnology) from Michigan State University, and spent two years as a Postdoctoral Research Associate at the U.C. Davis field station at Lake Tahoe before joining the faculty of Iowa State University.

Dr. Crumpton's research focuses on wetland processes and functions, including the dynamics of energy flow and nutrient transformation in wetlands, the fate and effects of agricultural contaminants in wetlands, and the role of restored and constructed wetlands in watershed hydrology and water quality. His work has been funded by a broad and diverse array of sources (*including USDA, USGS, USFWS, U.S.EPA, Iowa DNR, Iowa Department of Ag. and Land Stewardship, Iowa Natural Heritage Foundation, and Ducks Unlimited*) and published in a wide range of journals (*including Wetlands, Wetlands Ecology and Management, Journal of Hydrology, Hydrobiologia, Regulated Rivers: Research and Management, Water Science and Technology, Ecological Engineering, Journal of Water Pollution Control Federation, Bulletin of Environmental Contamination and Toxicology, and the Journal of Freshwater Ecology*). Much of his current work focuses on the development and application of performance forecast models for siting, design, and assessment of wetland restorations in agricultural watersheds. This work provided the research foundation for the Iowa Conservation Reservation Enhancement Program, a ten-year, \$89 million program using targeted wetland restorations to reduce nitrate loads from tile-drained agricultural watersheds.



**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands  
to Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Comments submitted by Dr. William G. Crumpton**

**POST MEETING ADDITIONAL COMMENTS**

My additional comments relate primarily to charge question 3.

Much of our panel's discussion seemed to focus on issues related to connectivity and while connectivity is important, it is in many ways more important to consider evidence of influence. This could be especially true in the case of "geographically isolated wetlands". In fact, the influence of "geographically isolated" wetlands could be increased by some degree of isolation, for example in the case of sediment retention and flood storage. Isolated depressional wetlands that are connected to downstream waters only during relatively infrequent storm flows could exert substantial influence on sediment transport and storm flows to downstream waters in part due to the relative isolation of these depressions from those downstream waters. Influence does not require a direct connection and "geographically isolated wetlands" could certainly alter material fluxes to downstream waters. Some of the effects of "geographically isolate wetlands" could be quantified based on available literature as has been done for tributary streams (for example an estimate of the flood storage volume of isolated depressions based on published values of their areal extent (for example using the estimates of Miller et al., 2009 for Iowa).

The apparent uncertainty over the connectivity of "geographically isolated wetlands" could be greatly reduced and the issues clarified by using an HGM approach to explicitly considering the links between wetland soils and hydrology. Wetland soils and hydrology are inextricably linked and soils can help in interpreting sources, pathways and frequency of water movement through wetlands and between wetlands and downstream waters. The NRCS technical note on "Soil Hydrodynamic Interpretations of Wetlands" is a very useful resource for this.

The report needs to clearly define and discuss issues related to cropped wetlands. Prior converted cropland and farmed wetlands are two distinct categories of wetland defined by the Food Security Act that have important implications with respect to both wetland protection and agricultural production. The 1985 Farm Bill established two categories of cropped wetlands, prior converted cropland and farmed wetlands.

*Prior converted cropland:* Wetlands that had been sufficiently drained prior to December 23, 1985 are referred to as prior converted cropland and are not treated as wetlands under the Swampbuster provisions of the 1985 Farm Bill. There are no USDA restrictions on further improving or enhancing drainage on prior converted cropland.

*Farmed wetlands:* Wetlands that had not been sufficiently drained prior to December 23, 1985 are referred to as farmed wetlands and are afforded protection under the Swampbuster provisions of the 1985 Farm Bill. There are restrictions on further improving or enhancing drainage on farmed wetlands. Farmers who improve the drainage of a farmed wetland beyond the "scope and effect of the original

drainage” could lose all USDA program benefits or face penalties. These penalties or loss of benefits can cost landowners tens- or even hundreds of thousands of dollars.

The report needs to clearly define and discuss the issues related to subsurface tile drainage and how that influences connectivity of “geographically isolated wetlands” to downstream waters. In much of the Corn Belt, subsurface tile drainage systems transport most of the water that leaves agricultural watersheds. For systems with surface intakes, tile drains could provide a direct connection to downstream waters. Regardless of one’s opinion over the importance of this connection, it is unacceptable to ignore this issue in a report that addresses the connectivity and influence of wetlands on downstream waters.

## RESPONSE TO TECHNICAL CHARGE QUESTIONS:

1. **This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.**
  - a) **Are these conclusions supported by the scientific evidence?**
  - b) **Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
  - c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The conclusion that all streams are physically and chemically connected to rivers is well supported if we incorporate a minor modification that seems consistent with the body of the report. Specifically, it is possible to have losing streams that are not hydrologically connected to downstream waters via channels and perhaps not chemically or biologically connected. I infer this as the basis for the report excluding certain channel origin wetlands that feed losing streams. The exception of certain wetlands spilling to losing streams as potentially not being connected to downstream waters is introduced in the *Executive Summary* on page 13, lines 285-289 and repeated numerous times throughout document.

285 ephemeral streams that originate from them). In non-riparian wetlands that are not  
286 connected to the river network through a stream channel (i.e., geographically isolated  
287 wetlands and wetlands that spill into losing streams), connectivity varies geographically  
288 within a watershed and over time, making it difficult to generalize about their connections  
289 to, or isolation from, downstream waters.] The literature we reviewed does not provide

With the exception of certain losing streams that may lack a connection to downstream waters, the conclusion that at least collectively streams exert a strong influence on the character and function of downstream waters is well supported. The report illustrates this through estimates of the fractions of river flow and material loads (nutrients, carbon, etc.) that originate in streams.

The report provides sufficient coverage of the relevant peer-reviewed literature on physical and chemical connections of streams to downstream waters with the possible exception of losing stream reaches (i.e., the possible isolation of losing reaches from downstream waters). Given the apparent inference in the report that certain losing stream reaches may not be connected to downstream waters, this particular concept should be clarified and supported with relevant literature.

In general, the literature was cited and summarized appropriately. The report does a particularly good job in summarizing the complex nature of stream networks including the major components and their spatial and temporal dynamics.

I offer no response with respect to the questions involving biological connections of streams to downstream waters as this is outside my area of expertise.

**2. This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.**

- a) Are these conclusions supported by the scientific evidence?**
- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The conclusion that wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network is well supported by the scientific evidence (with the possible exception of wetlands in riparian areas and floodplains of certain permanently losing streams that are never connected to downstream waters- these systems would be rare). The report illustrates this through literature documenting the unidirectional and bidirectional transfer of water and materials and transport and migration of organisms.

The conclusion that wetlands in riparian areas and floodplains of streams and rivers exert a strong influence on the character and function of downstream waters is well supported by the scientific evidence – at least for the systems collectively, and that qualification should be included in the conclusion.

The report provides sufficient coverage of the relevant peer-reviewed literature on physical, chemical connections of wetlands in riparian areas and floodplains to the stream networks. The literature was cited and summarized correctly. The report recognizes the uncertainty in quantifying exchanges between stream/river channels and their riparian areas/floodplains and provides sufficient documentation of the transfers without extending the analyses beyond what can be reasonably concluded.

3. **This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**

- a) **Are these conclusions supported by the scientific evidence?**
- b) **Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
- c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The conclusion that in the case of non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel, connectivity and isolation varies within a watershed and over time is well supported by the scientific evidence.

The conclusion that the literature reviewed does not provide sufficient information to document the connectivity of these systems is correct, but it should be noted that this is largely because the category includes a mix of wetlands that are truly geographically isolated and wetlands that are clearly connected to downstream waters. The report should attempt to provide guidance on how to distinguish these two categories (perhaps using soils and other indicators). The report distinguishes geographically isolated wetlands as surrounded by uplands but seems to include in this grouping all non-riparian/non-floodplain wetlands that do not outlet to a channel. This concept is introduced on lines 52-54 on page 3 of the *Introduction* and repeated throughout the report. It is well illustrated by Figure 3-18 on page 64 in section 3.4.2. Essentially the report places wetlands that spill over to a “swale” in the category of geographically isolated wetlands since swales can be “upland”. However, it would also include in this category prairie pothole depressions that spill over onto wetland flats or slope wetlands rather than to a channel. Wetland depressions that spill over to wetland systems (including wetland flats, slope wetlands or hydric swales) should be recognized as a separate category, distinct from wetlands that are completely surrounded by upland and thus more likely to be truly geographically isolated.

52           or ephemeral streams that originate from them). In non-riparian wetlands that are not  
53           connected to the river network through a stream channel (i.e., geographically isolated  
54           wetlands and wetlands that spill into losing streams), connectivity varies  
55           geographically within a watershed and over time, making it difficult to generalize  
56           about their connections to, or isolation from, downstream waters. The literature we

The report provides reasonable coverage of the relevant peer-reviewed literature on connection and isolation of non-riparian/non-floodplain wetlands to the downstream waters but does fall short in a few areas.

The report fails to adequately address the effect of subsurface tile drainage on connectivity of these wetlands to downstream waters. The report recognizes that surface drainage and ditching can directly increase connectivity to downstream waters (for example lines 5166-5170 on pages 249-250 of section 5.8.3.1). The report states that “When potholes are artificially connected to streams and lakes through drainage, isolation is eliminated and they become important sources of water and chemicals” (lines 4984-4985 on page 242 in section 5.8.1). However, the report is apparently referring only to surface drainage. Little consideration is given to the importance of subsurface “tile” drainage which is ubiquitous throughout the Corn Belt and many other areas. The report mentions only briefly that “drains fitted at the bottom of potholes connected to shallow subsurface pipes often discharge to open ditches and streams” (lines 5170-5171 on page 250 of section 5.8.3.1) but is silent on whether this constitutes a direct connection to downstream waters. This is an extremely important issue and the report should clarify the role of subsurface tile drainage (and especially surface intakes to these systems) in providing a connection to downstream waters. Specifically, do surface intakes of subsurface drainage pipes (“tile drains”) provide a direct connection to downstream waters for what might otherwise be considered geographically isolated wetlands?

5169    Ditches create new surface water outlets from potholes, allowing collected water to flow into  
5170    streams and rivers; drains fitted at the bottom of potholes connected to shallow subsurface pipes  
5171    often discharge to open ditches or streams (Ginting et al. 2000).

The report in part uses HGM (hydrogeomorphic) wetland classification and could benefit from a review of the wetland classes in this system. Important HGM classes in the Prairie Pothole Region would include for example depressions, flats, and slope wetlands. This classification is useful in that it helps to illustrate connections and surface flow paths in these landscapes.

The report should also provide information on the relationship between soils and wetland classes. Soils can be very useful in determining HGM wetland class, in identifying flow paths and connections, and potentially in distinguishing geographically isolated wetlands from depressions that are at least intermittently connected to downstream waters through wetland flats or slope wetlands.

The report makes the important point that increased surface outflow and connectivity is expected in wetter portions of the prairie pothole but extends this analysis only as far as the Red River Valley and ignores the much wetter and more interconnected wetlands of the Des Moines Lobe (lines 1434-1437 on page 77 of section 3.4.6 and lines 5138-5143 on page 248 of section 5.8.3.1).

1434 connections occurring between wetlands should be inversely proportional to local relief. Within  
1435 the PPR, precipitation generally decreases from east to west, while relief generally increases.  
1436 The easternmost physiographic region in the PPR is the Red River Valley, a relatively flat  
1437 ancient lakebed (Lake Agassiz) having deep deposits of silt and clay. Water can pond easily on  
  
5138 connections. Authors have reasoned that the relatively wet and topographically low Red River  
5139 Valley zone of the PPR should display greater surface water connectivity of potholes than either  
5140 the Drift Prairie or Missouri Coteau zones. Furthermore, they suggest that stream density will  
5141 impact the chance that pothole spillage connects to the larger river network. Thus, potholes in  
5142 the Missouri Coteau, with its limited network of streams, should be more hydrologically isolated  
5143 than potholes in the Red River Valley or Drift Prairie (Leibowitz and Vining 2003).

A broader analysis of this pattern for the Prairie Pothole is provided by Johnson et al. (2005. *Vulnerability of northern prairie wetlands to climate change. Bioscience 55: 863-873*). Their models of wetland water regimes suggest that spillover to downstream waters is a common occurrence in the wetter portions of the Prairie Pothole Region. For the Des Moines Lobe, spillover was expected in 87 years over a 95 year weather record. Because of the wetter climate, depressional wetlands on the Des Moines Lobe formed as interconnected systems with significant flow from upslope depressions through wetland flats to downslope depressions and from downslope depressions to receiving streams. In this regard, prairie potholes of the Des Moines Lobe differ from the more isolated basins that are typical of drier parts of the Prairie Pothole region. An analysis of soils illustrates these differences between the more interconnected wetlands of the Des Moines Lobe and the more isolated wetlands of the drier portions of the Prairie Pothole Region.

The literature is for the most part cited and summarized correctly. However, in several places (line 1435-1468 and others), the report incorrectly describes the subregions of the Prairie Pothole Region, essentially ignoring the Des Moines lobe. This is the southeastern and wettest portion of the Prairie Pothole and as suggested above, its wetlands might be expected to have greater connectivity to downstream waters.

- 4. This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**
- a) Is this conclusion supported by the scientific evidence?**
  - b) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**
  - c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The conclusion that in the aggregate, a class of streams or wetlands might have a substantial effect on downstream waters even though the influence of an individual stream or wetland might be small is clearly supported by the scientific evidence (and by simple common sense).

The report provides sufficient coverage of the relevant peer-reviewed literature on this topic although that literature is by design spread throughout the report in the treatments of streams, riparian/floodplain wetlands, and non-riparian/non-floodplain wetlands.

The literature relevant to this topic was cited and summarized appropriately although its dispersion throughout the document makes it less easily accessible than that of the other topics.



## **Kenneth W. Cummins, Ph.D.**

Adjunct Professor  
Department of Fisheries Biology  
Humbolt State University  
Arcata, CA

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Kenneth W. Cummins, Ph.D. is currently Adjunct Professor, Department of Fisheries Biology, and Senior Scientist, U. S. Geological Survey, California Cooperative Fisheries Research Unit - both at Humboldt State University.

Over the past 40 years, Dr. Cummins has been involved in research and teaching in the field of freshwater ecology, while on the faculties of Northwestern, Michigan State, Oregon State, Pittsburgh and Maryland Universities. He also held the position of Distinguished Scientist at the South Florida Water Management District in the Everglades Restoration Program.

*“The River Continuum Concept”* (RCC), which he co-authored, relates the physical template of watershed networks with the biological systems that overlay it, from headwaters to large rivers. After its publication in 1980, topics related to the RCC expanded to include; river- floodplain interactions, localized tributary effects on larger rivers, discontinuities in the RCC imposed by dams, and changes in freshwater invertebrate community composition along the RCC trajectory. He developed the *“Functional Feeding Group”* approach to the analysis of these invertebrate communities. Along with Drs. Richard Merritt and Martin Berg, he is author and editor of *“The Aquatic Insects of North America.”* This book, now in its fourth edition, contains tables which allow the categorization of aquatic insect genera by habitat and functional group. He is widely published in the field of freshwater ecology, some designated as citation classics. Over the last 30 years he has focused on the coupling between riparian vegetation and invertebrate and fish populations of streams.

### **Journals in which Cummins has published:**

Ecology; Ecol. Monogr.; Can. J. Fish. Aquat. Sci.; JNABS; BioScience; Limnol. Oceanogr.; Verh. Int. Verein. Limnol.; Freshwat. Biol.; J. Freshwat. Ecol.; Hydrobiologia; Arch. Hydrobiol.; Freshwat. Biol.; Freshwat. Invert.; Oikos; Annals Limnol.; Invert. Biol.; Amer. Midl. Nat.; Holarctic Ecol.; Environ. Toxicol. Chem.; Organic Geochem.; Annals Ent. Soc. Amer.; Ann. Rev. Ecol. Systemat.; Ann. Rev. Ent.; Trans. Amer. Microscop. Soc.; Ambio; J. Restor. Ecol.; Florida Sci.



**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands  
to Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Comments submitted by Dr. Kenneth W. Cummins**

- 1. This report concludes that all streams regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

The conclusions are supported by the scientific evidence.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

By and large the report does include the most relevant peer reviewed literature to address the question. However I have the following comments and recommendations.

Page Line Comment

- |    |        |   |
|----|--------|---|
| 2  | 32     | ... spiraling... Unlike standing waters where nutrient cycles are closed loops, the unidirectional flow of streams creates open cycles in which release of a nutrient is displaced from its uptake site. The open nature of the cycles needs to be made clear at the outset. (Also, 8, 184; 8, 190; and the entire section 9, 191-206 should include the concept that the cycles are open.)   |
| 11 | 253-60 | A major feature of dams is to reverse the seasonal hydrology of streams and rivers on which they are constructed. The purpose of most dams is to truncate peak flows in the normal season of high runoff (storage for dry season release and use) and to increase flows during these normal low flow seasons. This reversal of normal hydrological patterns has immense implications for life cycles of lotic organisms. This point should be made here or elsewhere.   |
| 15 | 342-44 | Furthermore... isolated. In fact, some ecologists have suggested using air-shed, watershed, and ground-watershed to categorize all the approximately definable inputs and cycles with in a region.  |
| 23 | 509-10 | Headwater streams are first- and second-order streams... I feel strongly that alternatives to this statement should be acknowledged. For example, the River Continuum Concept (Vannote et al., 1980, cited 4, 708 times so far) groups first-to third-order streams as those headwater streams in which riparian vegetation dominates the in-stream biology. Most order s one to three have canopy closure sufficient to <i>strongly influence</i> in-stream primary production (designated as P/R <1) and the input of plant litter that is the dominant energy base of stream ecosystem function in most headwater streams. |

Here, and elsewhere, the point should be driven home that stream order is a geomorphic concept and probably never should be inferred from blue lines on a map, which can represent anything from first-order to fourth-order depending on map scale. In addition, the stream class system of categorizing streams by fish-bearing condition (e.g., California Forest Practices Rules, Section 936.4) should be laid to rest. This is not a geomorphic defensible classification and should be permanently discouraged. [“Class I watercourses are defined as fish always or seasonally present onsite, including habitat to sustain fish migration and spawning. Class II waters are defined as 1) fish always or seasonally present off-site within 1000 feet downstream and/or 2) aquatic habitat for non-fish aquatic species. Class III watercourses do not have aquatic life present” (This is impossible at all seasons and in all years – e.g., aquatic Diptera, appear within days of flooding of forest access roads) “and are capable of sediment transport to Class I and II waters under normal high water flow conditions. (Cummins, K.W. and M.A. Wilzbach. 2005. The inadequacy of the fish-bearing criterion for stream management. Aquatic Sciences. *On line*; <http://www.birkhauser.ch>, pp 1-6).

- 24     531     ...symmetry ratio... another way is link number, which sums the total number of first-order tributaries entering a watershed of a given order. Fig. 3-1 shows no first-order tributaries entering directly into the third-order mainstem which would be quite unusual. Link number is a useful measurer for stream ecologists working at the watershed scale because the first-order tributaries are those in which the riparian influence on in-stream biological community composition and productivity is maximized
- 26     559     Fig. 3-3. The diagram’s horizontal bars give no indication about the massive controversy about the width of riparian areas. This point is the major element of all forest practice rules, including the sentinel Northwest Forest Plan, that define the width in terms of tree height in the riparian area. The point that need s to be acknowledged (driven home), is that stream ecologists, fisheries managers, and forestry managers all have different concepts (or biases) about the definition of the width. For example, stream ecologists may focus on the width necessary to provide the width that supplies plant litter that constitutes the primary energy source of headwater stream ecosystems, fisheries managers are concerned with the width necessary to insure the input of large wood which is the mainstay of fish habitat in streams and rivers in general, and forestry managers are concerned with how much width will be excluded from harvest by almost all forest practices rules. So, for scientific, Endangered Species Act, and economic reasons defining the width, or the criteria for defining the width of the riparian zone is far from a trivial matter. At least replace the end bars on the riparian widths in Fig. 3-3 with a dashed line at the ends. The figure caption should explain that the dash lines indicate that the boundary of the riparian zone depends upon the function being considered (e.g., Gregory et al., 1991).

- 51 1000 Figure 3-14). Also, dissolved organic matter (DOM) forms complexes with divalent cations, primarily Ca, converting DOM to fine particulate organic matter (FPOM, particle size < 1mm) and is taken up directly by benthic bacteria. This significantly delays the export of organic matter down river. DOM almost universally accounts for 50% of all the organic matter in transport in all order streams (Vannote et al., 1980 and the Minshall et al., River Continuum publications). This retention of FPOM, rather than loss as DOM, has major consequences for stream and river invertebrates and is likely a major factor in the productivity of hard water (calcium rich) streams.
- 80 1484 Swanson et al. (1987) suggest that short recurrence intervals involve flows too small to cause significant changes in stream channel geomorphology, and very long recurrence intervals cause very major alterations in channel form, but the intermediate recurrence intervals are the events that have the major effects in shaping the current condition of most channels.[Swanson, F. J., L. E. Benda, S. H. Duncan, G. E. Grant, W. E. Megahan, L. M. Reid, and R. R. Zimmer. 1987. Mass failures and other processes of sediment production in Pacific Northwest forest landscapes. Pp. 91-138 *in*: Salo, E. O. and T. W. Cundy. (eds.). Streamside management: forestry and fisheries interactions. Institute of Forest Resources, Univ. Washington, Seattle. (If the NRC publication is cited, this one should be eligible as well; it was reviewed by outsiders.)]
- 108 2106 Cite Cushing et al. (eds.), 2006. This 817 page volume includes chapters by worldwide authors on streams and rivers of North America, Central and south America, Europe, Africa, Asia, Australia and New Zealand, and Oceania. The editors charged the authors with using data from streams and rivers in their respective regions and comparing it with the River Continuum Concept (Vannote et al., 1980). The comparisons are about linkages (connectivity) between headwater streams and large rivers on a world wide scale. The introduction by the editors presents an overview of stream ecosystems. The River Continuum Conceptual Model (Vannote et al., 1980) is reproduced in the Introduction. This is the model that relates stream/river ecological structure and function to the position along the downstream trajectory. (Cushing, C. E., K. W. Cummins, and G. W. Minshall. 2006. River and stream ecosystems of the world. Univ. California Press, Berkeley 817 p.)
- 110 2145 ...108 m for whole leaves... This compares to the 100 m in Cummins et al. (1989) and not to the 1000 m cited in this report.
- 112 2197 ...snow melt. Approximately 50% of transported carbon was DOC in all streams (orders 1-8) covered in the River Continuum studies (Vannote et al., 1980, Minshall et al., 1983, 1992).
- 112 2206 ...river network. An important point here is that anaerobic storage of CPOM, e.g., leaf litter, greatly delays breakdown of CPOM to FPOM in the absence of hyphomycete fungi and shredders, both of which are obligate aerobes (Cummins et al., 1980. [Cummins, K.W., G.L. Spengler, G.M. Ward, R.M. Speaker, R.W. Ovink,

- DC Mahan, and R.L. Mattingly. 1980. Processing of confined and naturally entrained leaf litter in a woodland stream ecosystem. *Limnol. Oceanogr.* 25:952-957.]
- 120 2382 Wilzbach and Cummins (1989 ) demonstrated a higher % mortality among drifting individuals than their benthic counterparts. This raises the possibility that a significant amount of invertebrate stream drift is destined to have no impact on downstream colonization of invertebrates, with the primary effect being the contribution being to the downstream detrital suspended load. (Wilzbach, M. A. and K. W. Cummins. 1989. An assessment of short-term depletion of stream macrobenthos by drift. *Hydrobiologia* 185: 29-39.)
- 146 2970 ...gatherers, the dominant group... the term is defined, but as in the case of shredders (which was not defined or referenced when used) no citation is given. There are a great many that could be used, e.g., Cummins 1974, Cummins and Klug 1979. [Cummins, K.W. 1974. Structure and function of stream ecosystems. *BioScience* 24: 631-641; Cummins, K.W. and M.J. Klug. 1979. Feeding ecology of stream invertebrates. *Ann. Rev. Ecol. Syst.* 10:147-172; the designations are also part of the River Continuum Concept.]
- 148 3002 ...reaches 500 and 1,000 m upstream. Distance traveled by the majority of introduced leaf litter in a forested second-order stream by reported to be about 100 m by Cummins et al. (1989). [Travel distance of leaf litter was reported from the time the litter is wetted. Senescent Ginkgo leaves were used in these experiments; they are bright yellow and remain so for several weeks because they are very resistant to biological processing. Also, the leaf shape is unlike any of the native riparian tree species in eastern headwater streams.]

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The Literature that was cited was summarized correctly.

**2. This report concludes that open water and wetlands and riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river net work, and that their functions exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

The conclusions are supported by the scientific evidence.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

By and large the report does include the most relevant peer reviewed literature to address the question. However I have the following comments and recommendations.

<u>Page</u>	<u>Line</u>	<u>Comment</u>
7	161	...rivers. At some point, perhaps here, cases in which headwater streams are not the initial source of river networks should be flagged. For example, the Yellowstone River (one of the longest and largest un-dammed rivers in North America) originates from Yellowstone Lake. The lake itself is fed by numerous small tributaries which are not episodic connections. This natural configuration conforms to essentially all human-constructed reservoirs in North America.
175	3573	...outside edges of riparian areas... See comment 26, 559 (Fig. 3-3). This implies the width of riparian areas has been defined (as argued at 26, 559, there is little agreement about this, because the width is dependent upon the function being considered or the management objectives dependent upon the width as define by regulations. For example, foresters interested in timber harvest will argue for the smallest width possible while fisheries managers will argue for a width sufficient to provide recruitment of LWD.
177	3615	...such as black willow... As discussed at 74, 1363, the physical bank stabilization characteristics if black willow need to be balance against the potential disruptive effects on the aquatic ecosystem involved, e.g., stream or wetland. A very important point about connectivity between the riparian zone and the adjacent aquatic system and, therefore, the connectivity downstream is that the plant species composition of the riparian has a very significant impact on the timing and nature of these downstream contributions. (e.g., Cummins et al., 1989).
184	3771-72	Allochthonous inputs...food webs... (reviewed in Tank et al., 2010). This could use some other review references (e.g., Cummins 1974, Vannote et al. 1980, Cummins 2002) and many others). [Cummins, K. W. 2002. Riparian-stream linkage paradigm. Verh. Verein. Limnol. 28: 49-58.]
187	3842-44	Thus, lateral... river systems. Here or elsewhere cite Junk et al., 1989. Most stream ecologists would cite this paper as one of the major additions to the River Continuum Concept.  [Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The Flood Pulse Concept 9n river floodplain systems. Pp 110-127 in: Dodge, D. P. Proceedings of the international large river symposium. Can. Spec. Publ. fih. Aquat. Sci. 106.]
189	3881-82	See also notes about black willow (74, 1363; 177, 3771-72.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Literature was cited and summarized correctly. (Except see note at 184, 3771-72)

3. **This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream rivers. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**

**a) Are these conclusions supported by the scientific evidence?**

The conclusions are supported by the scientific evidence.

In general they are supported by the literature cited. However, I find this section very hard to evaluate objectively because the reason for separating out NRCWs as a class of connectivity is not clear. As noted in the underlined portion of the question above, there is no reason for this conceptual category.

There was a lot of discussion at the Committee Meeting about a reorganization of the information that was presented in the Document. I think the general thrust of the recommendation would improve the Document *and* not require much, if anything, in the way of new information.

The organization would not be levels of connectivity but rather functional classes of connectivity: hydrologic, physical (geomorphic), chemical (nutrients/ pollutants), and biological (ecological). Within each of these classes there would be continua of connectivity described as probabilities. Namely spatial and temporal probabilities of degree of connectedness. As was suggested, a conceptual model could be presented for each. For example, ephemeral streams have a low probability of connectivity on any given day in any given year, whereas perennial streams have a near 100% probability of connectivity along the same time continuum. The more spatially separated streams and wetlands of various types are, the lower probability they will exhibit high connectivity on any time scale.

This more functional approach would provide, I believe, a better frame work for handling the problem of conceptual models for isolated (surrounded by uplands) wetlands and allows for the concept that there are no examples of biological isolation, because migrations will always bridge hydrologic, physical, and chemical isolation.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

This report includes the most relevant peer-reviewed literature on those topics, including evidence of connectivity and isolation as presented. However, if a different organization of the report is adopted, as discussed above, a reorganization of the references cited would be

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Literature was cited and summarized correctly. Yes.

4. **This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution of an entire class of streams or wetlands (e.g.; all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**

**a) Is this conclusion supported by the scientific evidence?**

The conclusions are supported by the scientific evidence.

**b) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**

This report includes the most relevant peer-reviewed literature on those topics, including evidence of connectivity and isolation. This question has already been addressed in detail under the other charge questions. There seems little reason to simply transfer those comments (especially Charge Question 1) to this spot. I find the charge question redundant. Whereas the first three charge questions more or less apply to sections 3, 5 (5.1-5.3) and 5.4 of the report, respectively. There is no separate section that corresponds to Charge Question 4. If one uses the find option in Word and inserts intermediate or ephemeral streams or small wetlands in the search, one or both of these appear in essentially every subsection of the entire report. In reading the report I concluded that these entries were accompanied by appropriate citations. The comments provided under Question 3 apply here as well. If the Report was organized functionally, this section would be subsumed under each of the functional conceptual models.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The reviewed literature was cited and summarized correctly, *or* relevant comments were covered under the first three Charge Questions (e.g., comments about adaptations by invertebrate life cycles to accommodate periodic drying, in which the annual predictable seasonal flows of intermittent streams have more taxa adapted to the condition than in ephemeral streams, in which annual flows can only be described in terms of probabilities).

**Additional Comments**

<u>Page</u>	<u>Line(s)</u>	<u>Comments</u>
2	28	... plants, microorganisms, and...
4	81	replace <i>lack</i> with back
8	176	...series of complex physical, chemical, and biological alterations...
10	223	... lakes and lakes and reservoirs that form nodes in river systems.
12	261-2	...of sediment and organic matter... before they enter...
13	306-8	The impacts ... habitat, and ecology. The concept discussed in 11, 253-60 also applies here.

- 15 334 ...and invertebrates and vertebrates between...( fish and amphibian eggs have been isolated from migratory ducks feet)
- 17 398 ... the term... Then why use it?
- 19 424 ...oxbow lakes, “node” and pater noster lakes
- 20 443 ... scientific community... not those ignoring non-peer reviewed literature. Also, the statement about peer reviewed literature only being used is not true – p 311, 7055, National Research Council 2002 reference was not peer reviewed literature.
- 21 477-8 Again, I would argue that this report has a more thorough and unbiased literature review than most “peer reviewed” papers.
- 25 539 First Vannote et al., 1980 citation. Introduce River Continuum Concept phrase used therein.
- 25 546 Fig. 3-2. You need a magnifying glass to distinguish ephemeral streams.
- 27 583 Use an acronym for riparian/floodplain wetlands (R/FWs) or spell out non-riparian and channel origin floodplains (NRCWs). Use acronym for both or spell out both throughout the document.
- 28 661-2 See comment at 20, 443 above.
- 33 689-90 ...and references therein). This is a useful phrase to add where warranted because it indicates at least a partial review of the subject is included; could be useful other places in the report.
- 34 699 ...precipitation and are not seasonally controlled.
- 34 715 ...Hunter et al., 2005) and have major consequences for the distribution and seasonality of stream biota.
- 39 774 Fig. 3-10 has a much better representation of ephemeral streams than Fig. 3-2 (25, 546).
- 42 826 Delete *has*.
- 48 929-31 This is another argument for using link number. (see 24, 531; introduced at 122, 531 as useful but probably should be introduced here.
- 50 964 Vannote et al., 1980 should also be cited here.
- 51 1001 ...be eaten by other invertebrates and by aquatic vertebrates, especially juvenile fish that eventually ...
- 51 1001 Delete *further*; ambiguous.
- 52 1006 Fig. 3-14. This is an interesting take on the original Vannote et al., 1980 conceptual model. Perhaps a citation or two would be warranted here.

- 53 1017 ...basin can be transported back to a river only by terrestrial (over land) movement and not by a hydrological pathway.
- 54 1047-8 ...100 year floodplain. Introduce the concept of recurrence intervals (it appears later in the report.
- 56 1104 A statement is warranted about the “man-made paving” of essentially all urban watersheds in the U.S. resulting in quick flow as the rule.
- 59 1139 The Metolius River emerges and immediately assumes the ecological characteristics of a fourth-order river, with no headwater biological inputs and constant year around flow and temperature that completely alters life history patterns typical for streams of the region. (Fig. 3-15E; 57, 1105.)
- 61 1180 Define stream power (math formula) here or elsewhere.
- 63 1215 Fig. 3-17. Perhaps point out that C fits the pattern of quick flow for “paved” urban stream watersheds.
- 65 1240-42 See comment for 11, 253-60.
66. 162 Fig. 3-19. The use of link number can be seen in the figure. The trellis watershed is a third-order with a link number of 13 and the fourth-order dendritic watershed has a link number of 14. Riparian-dependent headwater ecological effects would be greater in the third order watershed.
- 73 1344 ...Eikeland 1988, *add* Rader, 1997, ... [Rader, R. B. 1997. A functional classification of the drift: traits that influence invertebrate availability to salmonids. Can. J. Fish. Aquat. Sci. 54:1211-1234.]
- 74 1363 ...movement and alter ecosystem function as in the case in which stream bank stabilization is accomplished by planting non-native willow to replace various species of alder. Alder (nitrogen fixers) litter is utilized at 5 to 10 times the rate of willow in headwater streams.
- 74 1374 ...al. 2011) and form a discontinuity in the normal stream-order related progression in stream ecosystem structure and function. (Ward, J. V. and J. A. Stanford. (eds.). 1982. The ecology of regulated streams. Plenum, N. Y. 398 p.
- 81 1151 ...and ephemeral streams, even though these watershed represent only ??% (small) of the land area of the United States.
- 82 1517-18 Another argument for link number inventory.
- 82 1519-30 Make it clear that stream order is a geomorphic classification and *not* a blue line map criterion. If the tenets of connectivity in this report are to be honored, development of new watershed concepts and advancement in research and land management plans must not be blue line map based.

- 83 1551-53 As per the statement on 82, 1526 (...Despite this underestimation...), this raises important questions about the data.
- 85 1604-06 Again, this might be a useful approximation, but it shows that, in general, map blue line analysis cannot be used to clarify the actual physical, chemical, and, especially biological, importance of geomorphic first-order channels in a watershed.
- 85 1608 ...and river flows, as long as headwater streams are defined as second-order channels.
- 87 1630 ...return interval... First mention of recurrence interval. Here, or elsewhere it should be defined (calculation method) and its utility discussed.
- 91 1706 ...Suspended sediment... The question of suspended fine particulate organic particles should be acknowledged. FPOM is a significant contributor to turbidity (first to be entrained on the rising limb of the hydrograph and the last to settle out on the falling limb) and biologically by far the most important component of the suspended load.
- 93 1763 ...inorganic + organic... First mention of the organic component; should appear earlier.
- 94 1796 LWD in stream of the western Cascades in Oregon measured to have been in place for over 100 years.
- 96 1838 ...important habitat for aquatic life... Not just habitat; LWD has a major role as a long term source of slowly processed DOM and FPOM that is utilized by stream microbes and invertebrates.
- 97 1858 ...diel changes typical of intermediate sized streams... and rivers. Larger daily temperature excursions in mid-sized rivers is one of two reasons proposed (Vannote et al., 1980; orders 4-6) for the usually maximized biological diversity of these rivers. (Aquatic organisms have differing temperature optima, and a wide daily range of temperature excursion provides more species to spend at least part of every 24 hours in their optimum range.)
- 100 1915 ...chemical linkages through open cycle spiraling.
- 107 2088 ...terrestrial plant litter... (in addition to leaf litter, other riparian plant parts can dominate seasonally, e.g., catkins.
- 108 2106 Cite Petersen et al., 1989. [Petersen, R.C., K.W. Cummins, and G.M. Ward. 1989. Microbial and animal processing of detritus in a woodland stream. Ecol. Monogr. 59:21-39.
- 109 2113 In this reference (and Vannote et al., 1980, and most of the other related ones I know of) headwater streams would be orders 1 – 3.
- 112 2187 .....downstream (Petersen et al., 1989, Gomi et al., ...
- 112 2198 ...et al., 2007) or in spring when other plant parts are shed, e.g., bud scales, flowers, catkins).

- 113 2219 ...et al., 2005). Diatoms continue to photosynthesize and invertebrates continue to feed and grow at 0°C. In fact, the majority of shredders accomplish all of their growth in the winter and remain inactive all summer in streams in forested areas (Cummins et al., 1989).
- 114 2235 The main point of the note here is that it should be acknowledged that connectivity can be on a diurnal scale as well as longer time periods. Weekly grab samples for DOC at 10 locations throughout the Augusta Creek were taken in southwestern Michigan for two years. Locations were sampled in sequence each week from 1 through 10 in the same sequential order. The data showed significant differences in DOC concentrations between the sites. When samples were taken every 2 hours over 24 hours at 1 site, the difference in the values were equal to the difference in the values between the 10 sites over 2 years. What appeared to be differences between sites over the 2 years were due entirely to the time of day when the samples were taken which was essentially the same each week because of the regular sampling schedule.
- 119 2374 Many invertebrates have life cycles that “expect” (are adapted to) dry and/or wet and /or hot or cold periods for the completion of their life cycles. Some may even require these periods.
- 120 2380 .....drifting insects (Rader 1997, Nakano...
- 120 2388 ...et al., 2006) and diel invertebrate behavioral patterns that are independent of flow (Rader 1997).
- 122 2439 ...higher prey and lower predator densities...
- 129 2605-06 Most often the *only* shrubs and trees in grassland biomes are along the water courses. This has significant implications for the in-stream biology (e.g., shading, litter inputs).
- 135 2737-38 flooding and drying..., spur successional sequences. Flooding is just as important in forested streams in resetting algal succession.
- 137 2765 ...surprisingly rapid. Why surprising? This is merely an example of the adaptation one would expect.
- 138 2808 ...was once limited by floods,... Is there post glacial evidence for this? Or, is “once” merely before agriculture cut the prairie?
- 146 2470 The functional feeding group (FFG) for categorizing freshwater invertebrates (e.g., Cummins and Klug 1979, Merritt et al., 2008) should be used (and defined) throughout the Report. There is a large literature extending over 30 years that utilizes this functional categorization on a world- wide basis (e.g., Cushing et al., 2002). The FFG meshes well with the concepts of connectivity.
- Arguably, the best indicator of normal (statistically probable) linkage (coupling) between riparian vegetation and stream biota is the presence of invertebrate shredders (e.g., Cummins and Klug 1979, Grubbs and Cummins 1996, Merritt et al., 2008). The

sequence is well known and has been demonstrated around the world (Cushing et al., 2006): 1) Riparian leaf is entrained in freshwater system; 2) leaf leaches DOM (up to 40 % of dry mass); 3) Leaf rich in carbon, lower in nitrogen, colonized by hyphomycete fungi (and bacteria), leaf species vary significantly in the length of time required for hyphomycetes to develop hyphal growth in leaf matrix – termed conditioning; 4) Shredder invertebrates seek out and feed on leaf or parts of leaf highest in hyphomycete biomass; 5) shredder feeding produces large amounts of FPOM (< 1 mm particle size feces and leaf fragments); 6) shredder feeding and temperature (number of degree days) accurately predict the period required to process a leaf from a given species of riparian plant (e.g., Petersen and Cummins 1974).

[Grubbs, S.A. and K.W. Cummins. 1996. Linkages between riparian forest composition and shredder voltinism. Arch. Hydrobiol. 137:39-58. Merritt, R. W, K. W. Cummins, and M. B. Berg. (eds.). 2008. An introduction to the aquatic insects of North America (4<sup>th</sup> edition). Kendall/Hunt, Dubuque, IA 1158p. . Petersen, R.C. and K.W. Cummins. 1974. Leaf processing in a woodland stream. Freshwat. Biol. 4: 343-368.]

- 146     2965     ...richness... Is this species richness? It would be more likely density.
- 146     2966-67     This is a basic tenet of the River Continuum Concept.
- 147     2977     ...filterers (macroinvertebrates ...suspended FPOM)... Citation? See 146, 2970.
- 148     3016-17     Again, it should be made clear that “richness” is taxa richness.
- 161     3270     [A note. This section makes one wonder if the organization of the report should have been by ecoregion, with the four aquatic system types as subheadings under each because the discussion of each of the four is so driven by ecoregion setting.
- 177     3622     ...length of the riparian area... This is ambiguous? Portion of the stream length that is bordered by riparian vegetation, or should this actually be width?
- 178     3650     ...productivity of *vascular* plants and algae...
- 179     3661     stream shading...be beneficial to fish and biota... Cooler temperatures beneficial to (non-fish) biota? According to Q10 relationships, cooler temperatures would slow production of invertebrates. How would the slowing of production of potential prey for fish be beneficial for fish?
- 179     3663     ...is used... used by managers?
- 181     3707     This sentence is too vague. What is being managed? The forest, fish, bank erosion, etc.?
- 181     3719     This may not be the place to address this, but many riparian corridors are dominated by shrubby or tree (red) alders that are nitrogen fixers and constitute a major source of nitrogen.

**Walter K. Dodds, Ph.D.**  
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Walter Dodds, University Distinguished Professor in Biology at Kansas State University (KSU), is recognized nationally and internationally as one of the leading researchers on aquatic ecology and is known for his work on river and stream ecosystems and how human influences affect water quality and biological integrity. His research has focused on whole system rates of N flux, scaling N transformation and flux rates in stream reaches to entire watersheds, and modeling the effects of land use on downstream transport of excess N. He leads the aquatic ecology research group for the Konza Prairie Long-Term Ecological Research program which has developed new conceptual models of grassland stream ecosystem function.

As a lead principle investigator at KSU, Dodds has received more than \$5 million in extramural funding from various agencies including the National Science Foundation, U.S. Environmental Protection Agency and Kansas Department of Health and Environment. In 1986 Dodds obtained a Ph.D. from the University of Oregon. He received an NSF Postdoctoral Fellowship at Montana State University in 1988 and joined the K-State Division of Biology faculty in 1990. He was hosted on sabbatical at the National Institute of Water and Atmospheric Research in Christchurch New Zealand in 1996. With over 125 refereed publications to his credit, Walter Dodds is the author of three books in his discipline. His textbook *Freshwater Ecology: Concepts and Environmental Applications* is one of the defining textbooks in the field.



**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands to Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Comments submitted by Dr. Walter K. Dodds**

This report is generally very well written. It clearly makes the case for connectivity of both streams and wetlands to downstream waters based on many published sources of information. I particularly like the framework of source, sink, refuge, transformation and lag to identify key functions. This approach really allows the issue at hand to be very clearly explored. However, this framework is not really clearly delineated throughout the document, and I think the document would be strengthened by some slight reorganization along these lines.

In a broad sense, the document indicates that the burden of proof should be on those claiming a stream or a wetland is not connected to downstream waters. The verbiage on lines 5617-5623 is a good example of this concept and potential problems with assuming lack of connectivity.

- 1. This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

For the most part, these conclusions are supported by the scientific evidence. There are a very few cases, where streams flow from wet areas (e.g., mountains) into dry areas (e.g., deserts), where streams might not connect to any downstream waters. However, these sites are the exception, not the rule.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

This report is well referenced. There are so many references on this subject, that it would be impossible to include them all. The document however, does cite plenty of references that clearly illustrate the main points of the report.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Yes, the literature was reviewed and cited correctly. One minor addition could be that there is one reference that is cited, Dodds and Oakes 2006 that indicates that intermittent streams are connected chemically to larger streams and rivers even during times of the year when the streams are not flowing. This point is not mentioned but is very important to the issue of connectivity.

I found the illustrative materials in this section quite useful and well done. However, I would like to see the figures such as 3-6 include diagrams of losing stream reaches as well, although figure 3-13 helps. Also a figure with a longitudinal cross section indicating hyporheic flow, and how such flow can connect isolated pools during dry periods could also be useful. Finally, Table 3-1 is a bit confusing as it

looks like everything flows into everything else through the river.. I would just lose the multiple italicized words in the first column that say “River”, or space out the individual rows further to make it clear that each row is not linking to the next. I think figure 3-14 is somewhat misleading as it ignores cycling through inorganic forms.

Line 1031, these streams flow during and immediately following precipitation.

A clearer discussion of when increased connectivity can be bad (e.g., introduced species) might be useful. The information was in the document, but buried. (e.g., at line 1408).

Line 1772, confluences are not “much like dams”, they can change longitudinal patterns, but much less severely and in very different ways from dams.

Line 1793. In the Flint Hills of Kansas, wood does not accumulate in small streams, and such streams are an important source of large wood to downstream rivers. This wood is very important habitat as well as a geomorphologic force in rivers. This statement might need to be qualified a bit.

Line 2495, might want to discuss the Falke and Gido 2006 (in references) work here on reservoirs disconnecting small streams from each other.

Line 2560. This could be stated more strongly. The evidence unequivocally demonstrates connectivity between streams and downstream rivers.

Line 2589 Work of Alexander et al. (2000) and Mulholland et al. (2008), Woolheim et al. (2008) both explicitly examine movement of materials along river network. This reference is also important Helton, A.M., Poole, G.C., Meyer, J.L., Wollheim, W.M., Peterson, B.J., Mulholland, P.J., Bernhardt, E.S., Stanford, J.A., Arango, C. & Ashkenas, L.R. (2010) Thinking outside the channel: modeling nitrogen cycling in networked river ecosystems. *Frontiers in Ecology and the Environment*, 9, 229-238.

Line 2718. The fact that nutrients are elevated in most ecoregions, and these are generally related to non-point source land use characteristics, is highly indicative of stream connection. Dodds, W.K. & Oakes, R.M. (2004) A technique for establishing reference nutrient concentrations across watersheds affected by humans. *Limnology and Oceanography Methods*, 2, 333-341.

Line 2750, these are still net heterotrophic, so they are derived to a lesser degree than forested areas.

Line 3059, this pattern was also probably driven by bass in the impoundments

Figure 4-9 the title is wrong

2. **This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.**

a) **Are these conclusions supported by the scientific evidence?**

Yes, these conclusions are supported

b) **Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

Yes, there is much current and relevant literature cited.

c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The only major issue I have with this section is not so clearly separating literature on riparian areas that are not technically wetlands from those that are. I understand that the authors of this document did not want to leave out riparian areas completely because it is clear that ANY riparian area is connected to the stream it abuts. However, there needs to be clearer separation of these. Perhaps a specific section on riparian areas generally, then a second on riparian wetland areas.

Table 5-2, not only is considering a stream without riparian influence limiting, it will give incorrect results. Also in this table, water storage needs to be mentioned

Line 4496, might also want to include work by David Galat

Galat, D.L., Fredrickson, L.H., Humburg, D.D., Bataille, K.J., Bodie, J.R., Dohrenwend, J., Gelwicks, G.T., Havel, J.E., Helmers, D.L., Hooker, J.B., Jones, J.R., Knowlton, M.F., J. Kubisiak, J.M., Mccolpin, A.C., Renken, R.B. & Semlitsch, R.D. (1998) Flooding to restore connectivity of regulated, large-river wetlands. *Bioscience*, 48, 721-733.

Galat, D.L. & Lopkin, R. (2000) Restoring ecological integrity of great rivers: historical hydrographs aid in defining reference conditions for the Missouri River. *Hydrobiologia*, 422/423, 29-48.

Galat, D.L. & Zweimüller, I. (2001) Conserving large-river fishes: is the *highway* analogy an appropriate paradigm? *Journal of the North American Benthological Society*, 20, 266-279.

I am surprised there is not more on the Kissimmee restoration as wetland connectivity was essential to this project. The Dahm, C.N., Cummins, K.W., Valett, H.M. & Coleman, R.L. (1995) An ecosystem view of the restoration of the Kissimmee River. *Restoration Ecology*, 3, 225-238.

3. **This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**

**a) Are these conclusions supported by the scientific evidence?**

Yes they are. However, the authors could have made a stronger statement here. One way to look at the issue is that if a wetland is not connected at all to other waters, then the only output of water must be evaporation. If this is the case then wetlands must be saline because salts will collect. As many if not most of these wetlands are not highly saline, there is strong indication that most wetlands are indeed connected to downstream waters either directly or through groundwater.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

Yes, this is made very clear. Isolation is certainly an issue mostly with the biological data, and they cover this well.

There has been a good amount of work on groundwater connections in the Highland Lake District of Wisconsin, and these connections include wetlands. One reference on this might be :Hunt, R.J., Strand, M. & Walker, J.F. (2006) Measuring groundwater-surface water interaction and its effect on wetland stream benthic productivity, Trout Lake watershed, northern Wisconsin, USA. *Journal of Hydrology*, 320, 370-384.

There is a huge amount of work on hydrologic and chemical connection in the Everglades. This should probably be covered a bit better here.

Line 4835. Why all of a sudden a section on human alterations here, where there are other human alterations throughout? This section is just a bit inconsistent with the rest of the report.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Yes, this is cited and summarized correctly.

Line 5177 the word detrimental is loaded, if it is a natural accumulation, then not quite sure how it is viewed as detrimental.

I am not really clear on how vernal pools are substantially different than the prairie potholes for the purposes of this document. The criteria on 5345 could apply to many of them.

- 4. This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**

**a) Is this conclusion supported by the scientific evidence?**

Yes, this is a very important point of this document. This point is actually true for any non-point pollution source, and the entire field of watershed management and TMDL's is based on this idea. Once the systems are known to be connected to receiving waters, then it is a clear fact that small individual systems might have a large effect in aggregate.

**b) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**

As far as I know, yes.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

As far as I know, yes.

**Post meeting comments:**

The meeting confirmed that the document is well written and makes the case for connection to downstream waters for most wetlands and all streams.

In general, I left this meeting with the idea intact that connection of small streams to rivers is important biologically, chemically and physically. Furthermore, in aggregate, many small streams act to define the characteristics of the watershed and influences on the streams and rivers below. This is true for nutrients (adequately supported in document) and organisms (e.g., Fagan 2002).

The section on streams should include ideas from the literature on subsidies and feedbacks. For example marine derived nutrients from spawning salmon can influence small streams, but this material also moves down to larger rivers. There is substantial literature on this idea, the report could start with the book on this issue by Polis et al. (2004).

Wetlands are clearly connected to downstream waters. Several more references could be put in related to this idea (Devito et al., 1999, Richardson et al., 2004, McCormick et al., 2006, Strauss et al., 2009). Biological connections can also move nutrients among isolated water bodies (e.g., Manny et al., 1994, Post et al., 1998).

Some wetlands have very clear and fast connections to downstream waters, particularly those in more permeable unconsolidated sediments or karst areas (e.g., Malard et al., 1994, White et al., 1995).

Fagan, W.F. (2002) Connectivity, fragmentation, and extinction risk in dendritic metapopulations. *Ecology*, **83**, 3243-3249.

- Devito, K.J., Hill, A.R. & Dillon, P. (1999) Episodic sulphate export from wetlands in acidified headwater catchments: prediction at the landscape scale. *Biogeochemistry*, **44**, 187-203.
- Manny, B.A., W. C. Johnson and R. G. Wetzel. (1994) Nutrient additions by waterfowl to lakes and reservoirs: predicting their effects on productivity and water quality. In: *Hydrobiologia 279/280:121-132*. (Ed^Eds.
- Mccormick, P.V., Shuford, R.B.E. & Chimney, M.J. (2006) Periphyton as a potential phosphorus sink in the Everglades Nutrient Removal Project. *Ecological Engineering*, **27**, 279-289.
- Polis, G.A., Power, M.E. & Huxel, G.R. (2004) *Food webs at the landscape level*, University of Chicago Press.
- Post, D.M., Taylor, J.P., Kitchell, F.J., Olson, M.H., Schindler, D.E. & Herwig, B.R. (1998) The role of migratory waterfowl as nutrient vectors in a managed wetland. *Conservation Biology*, **12**, 910-920.
- Richardson, W.B., Strauss, E.A., Bartsch, L.A., Monroe, E.M., Cavanaugh, J.C., Vingum, L. & Soballe, D.M. (2004) Denitrification in the Upper Mississippi River: rates, controls, and contribution to nitrate flux. *Canadian Journal of Fisheries and Aquatic Sciences*, **61**, 1102-1112.
- Strauss, E.A., Richardson, W.B., Cavanaugh, J.C., Bartsch, L.A., Kreiling, R.M. & Standorf, A.J. (2009) Variability and regulation of denitrification in an Upper Mississippi River backwater.
- Malard, F., J.-L. Reygrobellet, J. Gibert, R. Chapuis, C. Drogue, T. Winiarsky and Y. Bouvet. (1994) Sensitivity of underground karst ecosystems to human perturbation - conceptual and methodological framework applied to the experimental site of Terrieu (Herauld- France). In: *Verh. Internat. Verein. Limnol.* **25:1414-1419**. (Ed^Eds.)
- White, W.B., D. C. Culver, J. S. Herman, T. C. Kane and J. E. Mylroie. (1995) Karst Lands. In: *Am. Sci.* **83:451-459**. (Ed^Eds.)

**James W. La Baugh, Ph.D.**

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**DEGREES:**

Delaware Valley College - 1973 - B.S. Biology; West Virginia University – 1978 - Ph.D. Biology (Limnology)

**PROFESSIONAL EXPERIENCE:**

Hydrologist, Office of Hydrologic Research, Denver, Colorado, U.S. Geological Survey, July 1978 - March 1995. Hydrologist, Office of Groundwater, U.S. Geological Survey, Reston, Virginia, March 1995 to present. Research efforts have been directed at the hydrological mechanisms controlling chemical fluxes between lakes and wetlands, their watersheds, and the atmosphere, including directly measured contributions by groundwater. This includes investigation of chemical fluxes in saline and non-saline wetlands and lakes in semi-arid environments, and a lake in a humid environment. Research investigations have included work at sites in Colorado, Nebraska, North Dakota, Minnesota, New Hampshire, and Guam. Study of the interaction of lakes and wetlands with groundwater has included examination of multiple lakes and wetlands within common groundwater flow systems at sites spanning a climate gradient in mid-continent.

Publications related to the peer review of the EPA draft document have included: examination of various aspects of the water balance of wetlands (Water Resources Bulletin, 22:1-10), variability of wetland characteristics in relation to variable climate (Limnology and Oceanography, 41:864-870), hydrologic functions of prairie wetlands (Great Plains Research, 8:17-37), and hydrologic considerations in defining isolated wetlands (Wetlands, 23:532-540). Other related publications have pertained to the relation of closed-basin lakes to groundwater (Journal of Hydrology, 86:279-298; Canadian Journal of Fisheries and Aquatic Sciences, 52:754-767; Water Resources Research, 33: 2799-2812). Materials fluxes in water bodies interacting with streams as well as groundwater have been the subject of other publications (Limnology and Oceanography, 29:322-339; Water Resources Research, 21:1684-1692; chapters in - Mirror Lake: Interactions among Air, Land, and Water, University of California Press, 2009). Finally, some publications pertain to the general topic of the relation of groundwater to surface waters and watersheds (Ground Water, 47:989-1000; Science, 296:1985-1990).



**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands to Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Comments submitted by Dr. James W. La Baugh**

**TECHNICAL CHARGE QUESTIONS:**

(Note: underlined text in my original responses to the charge questions identifies critical or essential suggestions)

1. This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.

a) Are these conclusions supported by the scientific evidence?

The general synthesis of the cited literature provided in the report supports conclusion 1. The document, however, includes some conceptual inconsistencies that would benefit from resolution and clarification. These items are noted below.

- **Page 30, lines 634 to 635 – Figure 3-5** – Because the wetland is at a location where there is a break in slope, the absence of groundwater interaction with the wetland is remarkable. The fact there are local, intermediate, and regional flow systems is illustrated by Toth's work [see figure A-4 in Winter et al. (1998) <http://pubs.usgs.gov/circ/circ1139/pdf/circ1139.pdf> ]. Other figures in Winter et al. (1998) provide cross section diagrams of flow to rivers that includes arrows for local and regional flow, such as for a riverine valley – Figure 22 on page 39.
- If the intent of the use of a figure in this part of the introduction, however, is to indicate flow from groundwater follows shallow, intermediate, and deep flow paths prior to discharge to a river, each representing different amounts of time in transit, a better figure would be something like Figure 3 from Winter et al. (1998). An additional reference for the fact that groundwater representing different flow paths and times in transit discharge to a stream is Modica, E. 1999, Source and age of ground-water seepage to streams. U.S.Geological Survey Fact Sheet 063-99, 4 p. <http://pubs.usgs.gov/fs/1999/0063/report.pdf>
- **Page 33, lines 680 to 682** – Are all alluvial aquifers referred to as hyporheic zones? The parenthetical statement equating hyporheic zone with alluvial aquifer is problematic. To avoid confusing readers, the statement equating hyporheic zone with alluvial aquifers could be deleted.
- **Page 38, lines 768 and 769** – The phrase “aquifers contract” is unusual. Does the formation that is capable of conducting groundwater contract? Perhaps what was meant was that groundwater levels decline.
- **Page 42, line 826** – The phrase “This water has can alter the geomorphology...” is awkward. Revision for clarification would be useful.
- **Page 62, line 1195, and page 63, Figure 3-17** – Use of the term ‘impermeable aquifer’ is incorrect.

An aquifer by definition is “A body of rock that contains sufficient saturated permeable material to conduct ground water and to yield economically significant quantities of water to wells or springs.” Margret Gary, Robert McAfee Jr., and Carol L. Wolf, editors, 1972, ‘Glossary of Geology’, American Geological Institute, Washington, D.C.; or “An aquifer is a formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells or springs.” S. W. Lohman and others, 1972, Definitions of selected ground-water terms- Revisions and conceptual refinements, U.S. Geological Survey Water-Supply Paper 1988, 21 p.

- **Page 62, lines 1194 to 1200** – It would be useful to revise the paragraph to clarify the key points being made about flow systems while being consistent with correct use of technical terms. It is not at all clear why the explanation includes reference to intermediate or regional flowpaths. Intermediate and regional flow paths occur as a function of groundwater basin depth to width ratio (Toth, J.A., 1963, A theoretical analysis of ground-water flow in small drainage basins. Journal of Geophysical Research, v. 68, p 4795-4811). Also, surface waters with low permeability deposits in area of high topographic relief can receive water from beyond the local surface watersheds (Winter et al., 2003, Where does the groundwater in small watershed come from? Ground Water, v. 41, p. 989-1000).
  - **Page 135, line 2731** – Because vagility has the same meaning as capability of movement, is there any reason to use the term? Consider deleting vagility to simplify the text.
- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
- A useful reference regarding the interaction of streams and groundwater is absent from the references – Jones, J.B., and Mulholland, P.J., eds. 2000. Streams and Ground Waters, Academic Press, 425 p.
- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**
- **Page 42, line 828; page 175, line 3579; page 307, line 6921** – The name Meybloom in the citation is incorrect. Correct name for this citation is Meyboom.
  - I am not familiar with all of the literature cited in the document regarding the relation of streams to their connection with and influence on downstream rivers, therefore I am not able to judge whether or not all of the cited literature was summarized correctly.
- 2. This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.**
- a) Are these conclusions supported by the scientific evidence?**

The general synthesis of the cited literature provided in the report appears to support conclusion 2. Part of the text pertaining to the relation of open water and riparian wetlands to streams and rivers would benefit from clarification, as noted below.

- **Page 2, lines 38 and 39; page 10, line 225** – The phrase “...storage of local groundwater sources of baseflow in rivers,” could benefit from clarification. Was the intent of the text that riparian and floodplain wetlands are areas where groundwater flows to the wetlands rather than the adjacent river, thereby intercepting groundwater that otherwise would contribute to baseflow?
- b) **Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
- No response as this is not a focus of my area of expertise.
- c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**
- I am not familiar with all of the literature cited in the document regarding the relation of open water and wetlands in riparian areas and floodplains of streams and rivers to their connection with and influence on downstream rivers, therefore I am not able to judge whether or not all of the cited literature was summarized correctly.
3. **This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**
- a) **Are these conclusions supported by the scientific evidence?**

The overall synthesis of the cited literature provided in the report supports conclusion 3 in general. Parts of the text would benefit from revision for clarification and technical accuracy, as noted below.

- **Page 15, lines 336 to 344** – What is the source of the definition of “geographically” isolated? Why is it necessary to distinguish between geographical and hydrological isolation? The issue of connectivity would seem to be a function of the movement of water (and as noted on page 49, lines 949 -950 – movement of biota) independent of “geography.” The reason for the introduction of the concept of geographic isolation is missing. Also missing is a literature citation for the statement that vernal pools and coastal depressional wetlands are incorrectly referred to as geographically isolated. Why does this distinction matter?
- **Page 64, Figure 3-18** – An inconsistency appears to exist between what is shown in part B and the definition of “geographical isolation” on page 15, lines 340 to 342. Why is the non-channelized swale considered to be upland? By the definition on page 15, the wetland is geographically isolated when completely surrounded by upland. In order for water to exit the wetland to the swale, would not the swale have to be topographically lower than the wetland proper and be adjacent to it? The point raised here simply reinforces the reason for the inclusion of geological isolation in the context of examining connectivity is unclear.
- **Page 218, Table 5-3, second entry** – Is soil permeability the major factor controlling whether or not a wetland loses water by surface versus groundwater? What about the importance of

topographic setting with respect to the presence of channels or swales (see Figure 3-18B for example)?

- **Page 218, Table 5-3, fourth entry** - The connection of a non-riparian wetland to other water bodies through groundwater flow involves a time component. Even if the groundwater flow system that hydraulically connects a non-riparian wetland with an adjacent surface-water body is simply a local flow system, time is a factor related to the influence of the wetland on the adjacent surface-water body. If the flow path is one such that a particle of water takes years, decades, or longer to travel down gradient to the surface-water body, that length of time needs to be considered in the determination of how much of an influence the wetland has on the adjacent surface-water body. It might be useful to note that even when the wetlands are connected hydraulically through groundwater time affects the influence of the wetland on adjacent water bodies. The subject of length of time of groundwater flow in relation to wetlands is presented in Winter and LaBaugh(2003) cited in the EPA report.
- **Page 241, lines 4981 to 4982** – The use of the term impermeable throughout the document can be confusing. In most cases it seems that the contrast is more likely one of rivers or wetlands in high-permeability terrain in comparison with those in low-permeability terrain. In the prairie pothole region some water does infiltrate the soil so it would be more precise to indicate the soils and the glacial till comprise low-permeability terrain.
- **Page 250, line 5175** – One factor that can change the chemical characteristic of prairie pothole wetlands is loss of sediment due to wind erosion during periods when wetlands become completely dry. This phenomenon is documented in LaBaugh et al.1996, cited elsewhere in the document. Thus, unaltered wetlands with no surface outlet may also lose nutrients, sediment, and other chemical compounds during such episodes.
- **Page 254, lines 5259 to 5265** – One of the key factors affecting connections between prairie pothole wetlands and streams or river networks is the presence of ditches made by human activity. Mention of this is absent from this finding, even though ditching was noted in the supporting text that precedes this section.
- **Page 254, lines 5266 to 5269** – Ditching is a key factor enabling sediment, nutrients, and other chemicals that were present in wetlands to move to streams or rivers. The presence of a ditch to effect such transport is not conveyed in use of the phrase “Hydrologic sink or source functions of potholes can impact many features...” What exactly is meant by “multiple aspects of flow?” The concern here is that the finding is imprecise relative to what has been documented in the literature. In order for water to move across the land surface to a stream or river, either a surface connection needs to be made by a ditch or wetland water levels must rise to spill points in their basins that have a natural topographic path to a stream or river. Only when such hydrologic connections are made will water in the wetlands have the capability of transporting sediment or chemicals to streams.
- **Page 256, lines 5311 to 5312** – If the pools lie on impermeable substrates how does water infiltrate to form a shallow flow system? Perhaps the pools lie on low-permeability substrates rather than impermeable substrates. Also, if the substrate is impermeable, by definition it will not contain a surficial aquifer. A low-permeable substrate could contain a shallow groundwater system separated from a deeper regional aquifer by a confining bed.

- **Page 270, lines 5617 to 5623** – The content of the paragraph reinforces the need to provide a better definition of “geographically isolated,” as well as attribution to the source of that definition earlier in the document.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

- Arndt and Richardson discuss hydric soil development in prairie pothole wetlands (Arndt, J.L., and Richardson, J.L., 1988, Hydrology, salinity, and hydric soil development in a North Dakota prairie-pothole wetland system. Wetlands, v. 9, p. 93-108) but are not included in the references.
- A useful reference regarding wetland soils and water flow in a variety of landscapes is Richardson, J.L., and Vepraskas, M.J., editors, 2001, Wetland soils: genesis, hydrology, landscapes, and classification. Lewis Publishers, Boca Raton, Florida, 417 p.
- **Page 283, lines 6053 to 6056** – Entry for the cited literature source is not complete regarding publication information. The correct, complete entry should be revised as follows –Dickinson, J.E....2020...Middle San Pedro Watershed, Southeastern Arizona. U.S. Geological Survey Scientific Investigations Report 2010-5126, 36 p. <http://pubs.usgs.gov/sir/2010/5126/>
- **Page 325, lines 7588 to 7593** – Entries for the cited literature source are not complete regarding the publication information.

The correct entry for the Vining 2002 should be revised as follows – Vining, K.C, 2002....Water Years 1981-98. U.S. Geological Survey Water-Resources Investigations Report 02-4113, 28 p. <http://nd.water.usgs.gov/pubs/wri/wri024113/>

The correct entry for Vining 2004 should be revised as follows Vining, K.C., 2004....North Dakota and Minnesota. U.S. Geological Survey Scientific Investigations Report 2004-5168, 28 p. <http://pubs.usgs.gov/sir/2004/5168/>

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

- Literature pertaining to the overall topic and prairie pothole wetlands was summarized correctly in general. Areas requiring clarification are noted above in 3a.
- I am not familiar with all of the literature cited in the document regarding the relation of oxbow lakes, Carolina and Delmarva Bays, and vernal pools to their connection with and influence on downstream rivers, therefore I am not able to judge whether or not all of the cited literature pertaining to those types of wetlands was summarized correctly.

**4. This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**

**a) Is this conclusion supported by the scientific evidence?**

- In the section 6 of the document containing the set of conclusions (pages 266 to 271), the conclusion noted as 4 above was not presented. Nor was a fourth conclusion presented in Executive Summary at the beginning of the report. The absence of a fourth conclusion in the report, accompanied by supporting statements of key findings to support that conclusion, make answering this question and the following questions problematic.

**b) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**

- Insufficient information was provided to enable an answer to the question.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

- Insufficient information was provided to enable an answer to the question.

**Post meeting comments**

**In Reference to Charge Question Number 3, I offer the following** text as one possible solution to the dilemma posed by use of the term non-riparian and channel origin wetlands.

EPA connectivity panel - wetland classification note and suggestion

One document that discusses various aspects of wetlands in relation to hydrological characteristics is

Winter, T.C., and Woo, M-K. 1990. Hydrology of lakes and wetlands, p. 159-187, in Wolman, M.G., and Riggs, H.C., (eds.) Surface Water Hydrology. The Geology of North America, volume O-1. Geological Society of America, Boulder, Colorado.

In this document the authors note that existing classifications are not easily unified. In Winter and Woo (1990), a variety of lakes and wetlands were examined in the context of geologic settings, hydrologic processes controlling water balances, and physiographic settings.

In the EPA connectivity draft, the need to define channel origin wetlands is not compelling. If channel origin wetlands were simply thought of in terms of being the headwaters of a river, the need to include them as a separate category is eliminated. They would fall into the category of being associated with a river. The result would be two classes of wetlands, those associated directly with rivers, riverine wetlands (borrowing from Winter and Woo) - river headwater, riparian, and floodplain wetlands? and those not directly associated with rivers, non-riverine wetlands. Use of these two simple terms, riverine and non-riverine wetlands, also makes a distinction among wetlands: the first, those wetlands more likely to be directly connected by a surface water

connection with a river, and second, those wetlands less likely or unlikely to be directly connected by a surface water connection with a river. I suggest you substitute river headwater wetlands for channel origin wetlands in the text and include them in text pertaining to riparian and floodplain wetlands. Then substitute non-riverine wetlands for non-riparian wetlands throughout the document. Such revision might solve the wetlands classification dilemma discussed on January 30, 2012 during the panel meeting.

As an aside, Plate 2 from Winter and Woo (1990) is a nice portrayal of the fact that about half of North America is not humid. A figure for the lower 48 states derived from that plate is Figure 14, page 21 in

Reilly, T.E., Dennehy, K.F., Alley, W.M., and Cunningham, W.L., 2008. Ground-Water Availability in the United States. U.S. Geological Survey Circular 1323, 70 p. <http://pubs.usgs.gov/circ/1323/>

although the figure in Reilly et al. (2008) does not feature the gradients within the semi-arid to arid region shown in the plate of Winter and Woo (1990).

Comment on organization of the document:

It would be useful to consider reorganization of the document. Conceptual framework material regarding connectivity and influence appearing in both the stream (section 4) and wetlands (section 5) sections could be moved to section 3 (A conceptual framework) for consistency and clarity of presentation. Readers could then be referred to aspects of this common framework as needed in subsequent discussion of the relation of streams and wetlands to rivers.

One way of organizing a synthesis document is to present the conceptual framework as the main body of the text, with examples from different settings shown as ‘boxes’ or ‘sidebars’ – see Winter et al. (1998) as an example - <http://pubs.usgs.gov/circ/circ1139/> [this reference is cited in the current version of the document]. Another way of organizing a synthesis document is to present the conceptual framework as the main text, using ‘boxes’ interspersed to highlight particular technical nuances, with case studies as part of the text appearing after presentation of the conceptual framework – see Healy et al. (2007) as an example - <http://pubs.usgs.gov/circ/2007/1308/>

Comment regarding the definition of groundwater in the glossary:

The definition is correct. One of the other reviewers suggested labeling all subsurface as groundwater. Water in the unsaturated zone is not groundwater. See also page 4 of Heath, R.C., 1983, Basic ground-water hydrology. U.S. Geological Survey Water Supply Paper 2220, 84 p. <http://pubs.usgs.gov/wsp/wsp2220/>

Comment regarding use of the term watershed:

The document never clearly states that the term watershed as used in the report refers to surface water watersheds. It would be useful to note this convention when the word is first used. I may have missed something, but did not find groundwater watersheds mentioned in the text. Somewhere in the introduction, readers would benefit from a brief statement that groundwater watersheds also exist but might not coincide with surface water watersheds. Furthermore the boundaries of those watersheds can change over time in response to changing hydrologic conditions. This subject may fit in when the concept of groundwater flow

systems is introduced. As noted in my first comment regarding question 1. Figure 3-5 is inaccurate in its portrayal of local, intermediate, and regional flow systems. It would be better to use Toth's figure to do that. A local flow system is one in which groundwater flows from a water table high to an adjacent lowland. An intermediate flow system is one in which groundwater flows from a water table high to a lowland that is not immediately adjacent to the water table high. If the depth to width ratio of the aquifer is large enough, a regional flow system may also be present. Topographic divides do not always coincide with water table highs. Variability in the presence or absence of coincidence of surface water and groundwater watersheds is documented in Winter, T.C., Rosenberry, D.O., and LaBaugh, J.W., 2003, Where does the ground water in small watersheds come from? Ground Water, volume 47, number 7, pages 989-1000.

Comment about illustration of hydrologic landscapes of the continental United States and Alaska and Hawaii: Mention was made during the discussion that it might be useful to provide readers with the spatial context of ecoregions and hydrologic landscapes. Figure 8 on page S79 of Wollock et al., 2004 cited in the EPA document is the one that was suggested. It is also possible that inclusion of this figure, as well as the text needed to explain the content of the figure, might distract from the main focus of the conceptual framework because of the detail involved.

Comment about illustrating effects of pumping on groundwater flow paths interacting with a stream:

Figure C-1 on page 15 of Winter et al. (1998) shows effect of a pumping well on changes in groundwater flow paths.

Note about example illustrations:

Sources of hydrologic processes or connections (flow path) illustrations are provided herein. These are provided simply as examples of ways flow processes or connections have been illustrated in a variety of settings apart from the more general diagrams used from the Winter et al. (1998) reference in the EPA connectivity document.

[Note: the following two references are key citations for Florida wetlands that were not included in the EPA document, but should be. Essential references]

[Essential reference] Haag, K.H., and Lee, T.M., 2010, Hydrology and ecology of freshwater wetlands in central Florida – A primer. U.S. Geological Survey Circular 1342, 138 p.

<http://pubs.usgs.gov/circ/1342>

[Figure B-1, page 17 – flow in relation to seepage wetlands; Figure 5, page 21 – flow in Florida karst terrane]

[Essential reference] Lee, T.M., Haag, K.H., Metz, P.A., and Sacks, L.A., 2009, Comparative Hydrology, Water Quality, and Ecology of Selected Natural and Augmented Freshwater Wetlands in West-Central Florida. U.S. Geological Survey Professional Paper 1758, 152 p.

<http://pubs.usgs.gov/pp/1758/>

[Figure 1, page 4 – water budget of isolated wetland with fluctuating water level; Figure 11, page 24 – example of flow system in relation to wetland]

Buszka, P.M., Cohen, D.A., Lampe, D.C., and Pavlovic, N.B., 2011, Relation of Hydrologic Processes to Groundwater and Surface-Water Levels and Flow Directions in a Dune-Beach Complex at Indiana Dunes National Lakeshore and Beverly Shores, Indiana. U.S. Geological Survey Scientific Investigations Report 2011-5073, 75 p.

<http://pubs.usgs.gov/sir/2011/5073/>

[Figure 3, page 5 – Effect of tile drain on flow]

[Essential reference] Tribble, Gordon, 2008, Ground Water on Tropical Pacific Islands—Understanding a Vital Resource. U.S. Geological Survey Circular 1312, 35 p.

<http://pubs.usgs.gov/circ/1312>

[Page 4 – Figure showing surface and groundwater flow paths; Pages 10 and 11 - various groundwater flow settings ]

Faunt, C. C., editor, 2009, Groundwater availability of the Central Valley Aquifer, California. U.S. Geological Survey Professional Paper 1766, 225 p.

<http://pubs.usgs.gov/pp/1766>

[Figure A9, upper part, page 21 – surface and groundwater flow paths in the Sacramento Valley]

Barlow, P.M., 2003, Ground Water in Freshwater-Saltwater Environments of the Atlantic coast. U.S. Geological Survey Circular 1262, 113 p.

<http://pubs.usgs.gov/circ/2003/circ1262/>

[Figure 3, page 4 – Surface water and groundwater flow paths in the Atlantic coastal plain]

Izbicki, J.A., Johnson, R.U., Kulongoski, J., and Predmore, S., 2007, Ground-Water Recharge from Small Intermittent Streams in the Western Mojave Desert, California. Chapter G in Stonestrom, D.A., Constantz, J., Ferré, T.P.A. and Leake, S.A., editors, 2007, Ground-Water Recharge in the Arid and Semiarid Southwestern United States. U.S. Geological Survey Professional Paper 1703

<http://pubs.usgs.gov/pp/pp1703/>

The entire report is a large document so chapter link is provided below.

<http://pubs.usgs.gov/pp/pp1703/g/pp1703g.pdf>

[Figure 4, page 163 – hydrologic features of intermittent streams in the Mojave Desert]

Planert, M., and Williams, J.S., 1995, Ground Water Atlas of the United States - California, Nevada. U.S. Geological Survey Hydrological Atlas 730-B,

[http://pubs.usgs.gov/ha/ha730/ch\\_b/gif/b025.gif](http://pubs.usgs.gov/ha/ha730/ch_b/gif/b025.gif)

(Also available as an Adobe Illustrator eps file)

[Figure 25 – block diagram of basin types showing groundwater flow relations to types of playas]

\* Documents referred to in general discussion, but not critical for the EPA document, except where noted:

Document related to the fact the concept of average conditions is outdated

Milly, P.C., J Betancourt, M Falkenmark, R M Hirsch, Z W Kundzewicz, D Lettenmaier, and Ronald J Stouffer, 2008: **Stationarity is dead: Whither water management?** *Science*, **319(5863)**, 573-574.

Document related to conceptual framework of geomorphology in relation to milldams

Merritts, Dorothy, Rahnis, Michael, Walter, Robert, Hartranft, Jeff, Cox, Scott, Scheid, Chris\*, Potter, Noel\*, Jenschke, Matthew\*, Reed, Austin\*, Matuszewski, Derek\*, Kratz, Laura\*, Manion, Lauren\*, Shilling, Andrea\*, Datin, Katherine\*, 2011 (in press), The rise and fall of Mid-Atlantic streams: Millpond sedimentation, milldam breaching, channel incision, and stream bank erosion: Reviews in Engineering Geology, special issue on “The Challenges of Dam Removal and River Restorations”, editors Jerome V. DeGraff and James E. Evans.

Document related to hydrological and biological interrelations pertaining to removal of invasive species from riparian zones

Shafroth, P.B., Brown, C. A., and Merritt, D.M., editors, 2009, Saltcedar and Russian Olive Control Demonstration Act Science Assessment. U.S. Geological Survey Scientific Investigations Report, 2009-5247, 143 p.  
<http://pubs.usgs.gov/sir/2009/5247/>

Document pertaining to analysis of changing hydrologic conditions in relation to potential for Devils Lake to spill to a river

Vecchia, A.V., 2008, Climate simulation and flood risk analysis for 2008-40 for Devils Lake, North Dakota: U.S. Geological Survey Scientific Investigations Report 2008-5011, 28 p.  
<http://pubs.er.usgs.gov/usgspubs/sir/sir20085011>.

Document that discusses the relation of hydraulic conductivity to presence/absence of groundwater watershed divides

Winter and LaBaugh (2003) cited in the EPA document. The source of the information regarding the importance of moderate to highly permeable versus poorly permeable geologic substrates is Haitjema, H.M., 1995. Analytic element modeling of groundwater flow. Academic Press, San Diego, California.

Documents pertaining to overviews of wetlands in the Nebraska Sandhills

[Essential reference] Novacek, J.M., 1989, The water and wetland resources of the Nebraska Sandhills, in van der Valk, A., ed. Northern Prairie Wetlands, Iowa State University Press, Ames, Iowa, p. 340-384.

Gosselin, D.C., 1997, Major-ion chemistry of compositionally diverse lakes, Western Nebraska. U.S.A.: implications for paleoclimatic interpretations, *Journal of Paleolimnology*, 17:33-49.

Document related to presence and characterization of playas:

[Essential reference] Wood, W.W., 2002, Role of ground water in geomorphology, geology, and paleoclimate of the southern High Plains, USA: *Ground Water*, v. 40, p. 438-447.

Document providing details about the dynamic nature of hydrological and biological interactions of prairie wetlands

Winter, T.C., ed., 2003, Hydrological, chemical, and biological characteristics of a prairie pothole wetland complex under highly variable climate conditions - The Cottonwood Lake area, east-central North Dakota: U.S. Geological Survey Professional Paper 1675, 109 p.

<http://pubs.usgs.gov/pp/1675/report.pdf>

Document related to movement of nutrient plume from infiltration ponds to nearby lake

McCobb et al., 2003, Phosphorus in a Ground-Water Contaminant Plume Discharging to Ashumet Pond, Cape Cod, Massachusetts, 1999. U.S. Geological Survey Water-Resources Investigations Report 02-4306, 69 p.

<http://pubs.usgs.gov/wri/wri024306/>

Document related to irrigation canal recharge of groundwater as source of baseflow in rivers inhabited by endangered fish species

Ely, D.M., 2003, Precipitation-Runoff Simulations of Current and Natural Streamflow Conditions in the Methow River Basin, Washington. U.S. Geological Survey Water-Resources Investigations Report 03-4246, 43 p.

<http://pubs.usgs.gov/wri/wri034246/>



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Mark Rains is an ecohydrologist with a B.A. in Ecology, Behavior, and Evolution (UC San Diego 1990), an M.S. in Forestry (University of Washington 1994), and a Ph.D. in Hydrologic Sciences (UC Davis 2002). He has nearly 20 years experience in the public and private sectors in the science, policy, and management of wetlands and rivers, including extensive experience in the functional assessment, restoration, and management of degraded wetlands and rivers. He currently is an Associate Professor of Ecohydrology in the Department of Geology at the University of South Florida, Tampa, Florida. He is also the President of Coshow Environmental, Inc. in Temple Terrace, Florida, and the Associate Editor for Aquatic Ecology for the Journal of the American Water Resources Association.

Dr. Rains' research is focused on (a) local- and landscape-scale hydrological connectivity, (b) the roles that hydrological processes play in governing ecosystem structure and function, and (c) the roles that science plays in informing law and policy. He pursues these efforts in a variety of surface-water and shallow-groundwater environments, including depressional wetlands, headwater streams and mainstem rivers, and mangroves and lagoons. Dr. Rains has additional service-related interests in sustainable water-resources development in poor, rural communities in Latin America and the Caribbean Basin, and extensive experience in consensus building at the intersection of science and policy in wetland regulatory programs, including past and ongoing work related to providing the scientific justification underlying the federal definition of "waters of the US" subject to regulation under the Clean Water Act. For the latter, he was awarded U.S. Environmental Protection Agency Scientific and Technological Achievement Awards in both 2007 and 2009.

Dr. Rains is the author or co-author of more than 25 peer-reviewed papers, more than 30 technical reports, and five peer-reviewed teaching tools. He also is the author or co-author of more than 50 posters/presentations delivered at a variety of regional, national, and international meetings and university colloquia.



## **Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands to Downstream Waters – A Review and Synthesis of the Scientific Evidence**

### **Comments submitted by Dr. Mark C. Rains**

#### **REVIEWER COMMENTS ON CONCEPTUAL FRAMEWORK:**

##### **SUMMARY**

The key flaw in the document is that you arbitrarily break the landscape into three components, make the focus of the document on the individual discussions of those three components, and therefore make it difficult for you to show the inherent connectivity across these components. To counter this, I think that you should make the conceptual framework the highest order of organization in this document. The conceptual framework should be the central point of the document—the rest of the document should be to support and better explain this conceptual framework. Then conceptual framework should start with the premise that all components of the landscape are connected, and that what differs is the degree to which they are connected and the importance of those connections to downstream systems. You should clearly explain hydrological, chemical, and biological connectivity—but especially hydrological connectivity—in the context of the relevant literature (e.g., Pringle 2001, Pringle 2003a, Pringle 2003b, Freeman et al., 2007), using clear diagrams to illustrate that connectivity extends from ridges to reefs and connects all of the individual elements discussed in the document. You also should clearly explain the broader conceptual framework that you build relating to the five functions or roles that wetlands and streams play (e.g., source, sink, etc.). Last, you should explain how this landscape-scale connectivity means that the cumulative effects of many wetlands and streams can be large, even if the individual effect of one wetland or stream may be small. This, then, should be the foundation to which you return throughout the document, always reminding the reader about how the supporting information in each of the three individual components relates to this conceptual model, and showing specifically how connections and their downstream effects are clear in some cases and not so much in others.

##### **DETAILED COMMENTS**

General Comment: Throughout the document, there were terminology problems that make the basic conceptual framework and the scientific evidence difficult to follow. The first problem relates to the various uses of the terms headwaters, headwater streams, and streams. These are often used interchangeably, even though they are not commonly used interchangeably, and are not defined as such in the Glossary. To improve clarity, the standard definitions in the Glossary should be used throughout the text. The second problem relates to the use of connectivity. At times, it is used independently; at other times, it is used following a specific modifier (e.g., biological connectivity). This would not be a problem if independent usage implied any or all kinds of connectivity. However, that doesn't seem to be the case; rather, independent usage often seems to imply hydrological connectivity, and perhaps even surface-water connectivity (e.g., l. 594-597). To improve clarity, independent usage should refer to the existence of any kind of connectivity, while modified usage should refer to the existence of a specific kind of connectivity.

General Comment: There are significant problems with some of the technical aspects of the conceptual framework, particularly in relation to how water gets from uplands to wetlands or streams or between wetlands and streams. This is a critical part of the conceptual model, because it underlies the complex pathways and controls on hydrological connectivity. Lacking a proper conceptual framework in this regard, the document will fail to make a strong case not only for hydrological connectivity but also for all types of connectivity at spatial and temporal scales that matter in a regulatory environment. I make numerous specific comments in relation to this below.

l. 522-523: Rains et al. (2006, 2008) would be good references for this condition.

l. 534-536: This sentence concludes that water flows “downhill”. This isn’t actually true. Water flows downgradient, where gradient is primarily due to differences in elevation (i.e., the downhill part of downgradient) and pressure. Pressure plays important roles in surface-water flows, but plays even more important roles in groundwater flows, including groundwater flows as they relate to the conceptual framework and the scientific evidence presented throughout each of the subsequent chapters.

l. 575-577: This is not the correct federal definition of a wetland. The federal definition of a wetland is a regulation—which carries the full force of law—that can be found at 33 CFR 328.3(b): “The term ‘wetlands’ means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.” This is very similar to a definition used later in the document (l. 3455-3456). What the authors refer to here is the Corps of Engineers Wetlands Delineation Manual (USACE 1987), which is guidance—which does not carry the full force of the law—on how to delineate a wetland and not a regulation—which does carry the full force of the law—on how a wetland is defined. One benefit of using the correct federal definition of a wetland found at 33 CFR 328.3(b)—which is more generic and inclusive, with rather vague boundaries—is that you won’t struggle so much in trying to explain what you are considering a wetland in the riparian and floodplain wetland discussion (l. 3531-3540).

l. 613-614: There are two primary types of aquifers: unconfined and confined. In unconfined aquifers, the upper surface of the saturated zone is defined by the water table; in confined aquifers, the upper surface of the saturated zone is defined by the confining layer, and the water in the saturated zone is under pressure and will rise up to the potentiometric surface if the confining layer is perforated (e.g., by a piezometer or even by a natural fracture, as occurs at many springs). See my comment titled “Figure 3-4”, below.

l. 614-615: This is an inadequate definition of groundwater, because it leaves the issue of water in the unsaturated zone undefined. I suggest that you define groundwater as all water underground, be it in the unsaturated or saturated zones, then distinguish between the two when necessary by referring to them specifically as unsaturated-zone (or vadose-zone) groundwater and saturated-zone groundwater, respectively.

l. 615-616: There are many saturated deposits that we do not commonly call aquifers. Clays, for example, are commonly saturated but are not commonly called aquifers, and are instead commonly called aquitards, perching layers, or confining layers, depending upon the role they are playing. Perhaps you mean highly permeable instead of just permeable, but if so then you chose poor examples as soil could be anything,

including low-permeability clay-rich soils, and rock has extremely low primary permeability, though it can have relatively high secondary permeability if there are abundant and well-connected fractures. You might instead say: “Relatively highly permeable materials (e.g., sand and gravel) that are saturated and in which groundwater is stored and transmitted are referred to as aquifers.”

Figure 3-4: This is an oversimplification that affects your conceptual framework. I suggest that you show both unconfined and confined aquifers here. I know that this is a bit confusing, but is critically important in understanding connectivity. Many waters are hydrologically connected by unconfined aquifers, but many others are hydrologically connected by confined aquifers, especially where confined aquifers are perforated and regional groundwater discharges to streams and rivers (e.g., Kish et al., 2010) or surface water recharges regional groundwater (e.g., Sinclair 1977).

l. 628-630: Kish et al. (2010) would a good reference at the end of the last clause as they showed that the vast majority of flow in the Hillsborough River, west-central Florida, was groundwater discharged from the Floridan aquifer, primarily at a single spring.

l. 631-648, Figure 3-5: I’ve lumped the text and figure here, because they are so closely related.

There are quite a few things wrong here, which stem from an oversimplification on the part of Winter et al. (1998), which is the referenced paper but not the original work, and a misinterpretation on the part of these authors. The original work, cited in Winter et al. (1998), was by Toth (1963). Haitjema and Mitchell-Bruker (2005)—who, incidentally, were students of Toth’s—showed that Toth (1963) was correct, but only for certain cases such as the special case in which he was working. The truth is somewhat more complicated, and relates to important controls by climate and geology, especially geologic heterogeneity. Still, you might decide to keep this, subject to some comments below, because there’s nothing really wrong with using terms like local and regional groundwater flows. (Although I must admit that I’ve never understood the distinction between intermediate and regional groundwater flows.) If you do, however, you need to revise Figure 3-5, which is incorrect. Local groundwater flows are from a local high to a local low. This is the case in Figure 3-5. However, intermediate and regional groundwater flows are larger in spatial scale and cross one or more groundwater divides (i.e., they cross under one or more potential local groundwater flows). This is not the case in Figure 3-5; the intermediate groundwater flow is from a local high to a local low (i.e., it’s another local groundwater flow) while the origin of the regional groundwater flow is a bit unclear.

Regardless, I think that this is an incomplete conceptual model of flow from uplands to rivers and wetlands. There actually are four pathways that water can take from an upland to a river or wetland (Figure 1; Knighton 1998).

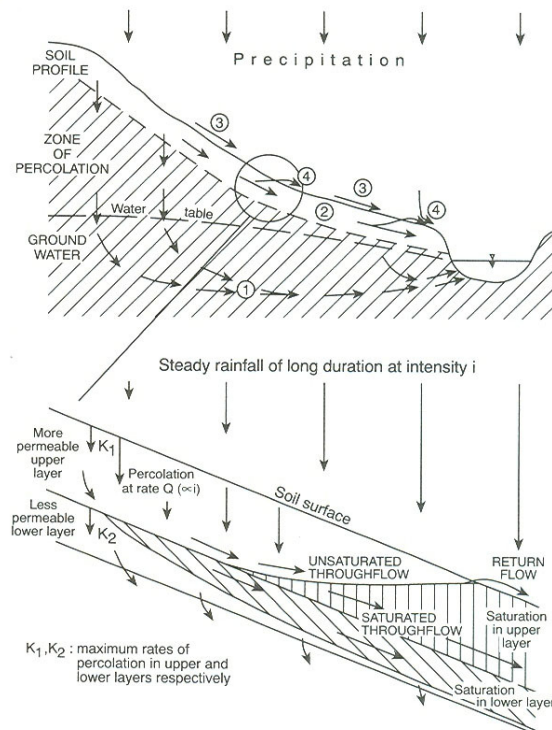
- Saturated Groundwater Flow (Pathway 1 in Figure 1): This is common flow of groundwater through the saturated zone. In this case, this would be an example of a local groundwater flow, though in other cases these might be intermediate or regional groundwater flows.
- Throughflow (Pathway 2 in Figure 1): This is quick flow through the unsaturated zone. This is commonly rapid flow through preferential flow paths, which can be soil cracks, animal burrows, or naturally formed soil pipes.
- Infiltration-Excess Overland Flow, or Hortonian Overland Flow (Pathway 3 in Figure 1): This is overland

flow where there is an unsaturated zone between the overland flow and the water table. This occurs when the rainfall rate exceeds the infiltration rate, a thin layer of saturation blankets the surface, and excess rainfall runs off.

- Saturated Overland Flow, or Dunne's Mechanism of Overland Flow (Pathway 4 in Figure 1): This is overland flow where the water table has risen to the surface and subsurface storage is full. This area varies through the course of the year and a given storm, giving rise to the term variable source area.

This is a more complete and technically correct conceptual model on which to base your reasoning. This is particularly true, because this emphasizes an important point, which I don't think comes through in the document, which is that headwaters continue from the headwater stream up to the summit of the adjacent hillslope. Headwater streams and adjacent hillslopes are, in fact, integrally connected, to the extent that headwater streams cannot exist absent the adjacent hillslopes. This point is central to the argument made by Nadeau and Rains (2007), and can be seen (explicitly, in some cases) in the way that they discuss the references therein. (See, specifically, the way they discuss Triska et al., [2007] and Meyer et al., [2007], though both are referred to not as "2007" but, rather, as "this issue".)

1. 676-679: Your definition of alluvium is somewhat confusing, in that there is a separate item in the list that comprises "at the base of a mountain", which could be either an alluvial fan (i.e., a fan of deposits deposited by water flowing off of a hillslope and into a valley) or a colluvial fan (i.e., a fan of deposits deposited by gravity pulling dry materials down a steep hillslope).



**Figure 1. This is copied from Knighton (1998). The text above refers to this figure.**

l. 720-722: You might follow this with a specific example. For example, wetlands can be seasonally isolated, connected by groundwater flows, and connected by surface-water and groundwater flows (Rains et al., 2006, 2008).

l. 794-796: A good reference for the first three items in this list would be Hammersmark et al. (2008); a good reference for the fourth and last item on this list would be Wolman and Miller (1960).

l. 896-899: A stream or wetland also can provide different functions at the same time, depending upon perspective. Rains et al. (2006) showed evidence that vernal pools simultaneously serve as a sink for nitrogen and a source for organic carbon, because nitrogen-rich/organic carbon-poor groundwater flows into vernal pools, the nitrogen is uptaken and converted to organic carbon, and nitrogen-poor and organic carbon-rich surface water and groundwater flow out of the vernal pools.

l. 990-993: The parenthetical list of “internal components” includes “alluvium” and “geologic materials”, but alluvium is a geologic material. I suggest omitting “geologic materials”.

l. 1016-1018: Water-borne contaminants can still be transported from a closed-basin depression to a river through groundwater flow.

l. 1053-1055: Rains et al. (2006, 2008) would be good references for this condition.

l. 1056-1059: You might also mention that downstream transport of seeds and/or propagules and seasonal flooding of riparian/floodplain wetlands is essential for the recruitment of vegetation, especially willows and cottonwoods (McBride and Strahan 1984, Scott et al., 1996, Mahoney and Rood 1998).

l. 1079-1222: I think that this entire discussion could be improved if it were integrated to include both climate and watershed characteristics at the same time, using Winter (2001) and Wolock et al. (2004) as the basis for the discussion. This is especially apparent when you compare the different the different hydrographs, which you try to do only in the context of climate, but are, in fact, the result of climate operating on watershed characteristics, an inconvenient fact that you end up having to mention briefly in l. 1134-1135.

l. 1080-1081: I don’t think that this statement is technically true, given the importance of geology, topography, and land cover. It’s probably better to say that “Climate determines the amount, timing, and duration of water available to the watershed.”

l. 1092-1093: How are you defining water surplus? Is it precipitation minus evapotranspiration? If so, then this sentence isn’t always true because the highest water surplus in snowy catchments is in mid-winter, when snowfall is greatest and evapotranspiration is negligible, but flow is low because most of the water is locked up in the snowpack storage.

l. 1098-1104: The first clause in the first sentence is only half true. See the descriptions of the two types of overland flow in my comment titled “l. 631-648, Figure 3-5” above. Because you start with only a half true premise, your subsequent examples are not altogether true. For example, overland flows can occur simply where water tables are shallow, regardless of rainfall intensities.

l. 1194-1200, Figure 3-17: I've lumped the text and figure here, because they are so closely related. The paragraph uses incorrect terminology. See my comment titled "l. 615-616" above. There isn't such a thing as an "impermeable aquifer", because an aquifer must be able to store and transmit water, by definition, and a deposit that is impermeable cannot do either, also by definition. Similarly, all aquifers are permeable, so the term "permeable aquifer" is redundant. Also, permeability is just one part of what controls the direction and rate of groundwater flow. Hydraulic head is the other part. Therefore, the entire discussion here about how permeability controls the direction of groundwater flow is not entirely correct. However, the general themes in the paragraph and in the figure are not entirely incorrect, except for the incorrect terminology in both the paragraph and the figure legend and explanation. Therefore, I think this can all be rescued, if the terminology is corrected and the controls on the direction and rate of groundwater flow are better explained. This can all be done better if you adopt the more complete and technically correct conceptual model I suggest in my comment titled "l. 631-648, Figure 3-5".

l. 1223-1318: This is a bit of awkward section because distribution is equally controlled by climate and geology, so this isn't really a standalone factor equal in importance to climate and watershed characteristics. You should probably state as much at the start, and could readily reference Tihansky (1999) as an example, as she shows that climate and geology control the distribution of sinkhole depressions in Florida, most of which are wetlands or lakes, particularly concentrating them in west-central Florida.

l. 1274-1278: This is not exactly true. Floodplains typically don't flood uniformly laterally away from the channel; rather, floodplains typically flood by engaging secondary and other paleochannels, sometimes by groundwater upwelling, other times by overbank flow (Tockner et al., 2000). These secondary and other paleochannels are all over the floodplain, and can be at the extreme edge of the floodplain complex, and the effect is that riparian/floodplain wetlands do not connect strictly as a function of distance from the main channel.

l. 1408-1413: Another excellent example is Hammersmark et al. (2008), who showed that the restoration of rivers, where incised channels are backfilled and the historic channels are reoccupied on the historic floodplains, can decrease the duration of dry season baseflow by (a) raising the alluvial water table and therefore increasing losses to evapotranspiration and (b) decreasing the hydraulic gradient and therefore the flux of water from the alluvial aquifer to the channel.

## TECHNICAL CHARGE QUESTIONS:

1. **This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.**
  - a) **Are these conclusions supported by the scientific evidence?**
  - b) **Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
  - c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

## SUMMARY

The conclusions are supported by the scientific evidence provided. This is the easiest task for the authors, because hydrological and ecological connectivity are fundamental tenets for these systems. However, I do have comments regarding some flaws and/or inadequacies in the scientific evidence provided as justification. (See, also, the detailed comments related to the conceptual framework in the section titled “Additional Reviewer Comments” below.)

## DETAILED COMMENTS

General Comment: There is incomplete discussion of perennial tributaries that are disconnected from perennial mainstems by seasonal or ephemeral reaches. This commonly occurs in the West, where tributaries are often perennial in the mountains but lose rapidly and are intermittent or ephemeral on the alluvial fans (Izbicki 2007). Furthermore, there is no discussion at all of closed basins that lack any kind of navigable water at all. I don’t know about now, but I do know that a few years ago, the U.S. Army Corps of Engineers (Corps) Albuquerque District was calling these isolated basins not subject to federal jurisdiction under the Clean Water Act (Parenteau 2004-2005). This document should provide clearly articulated evidence, one way or another, toward connectivity in these contexts to better enable decision-makers to resolve this policy conflict. Nadeau and Rains (2007) foresaw this, and separated this case out for special attention. Something like that might be called for here, too.

1. 1492-1537: This entire section would be greatly strengthened if you would include a review of some of the papers that show that hydrological and ecological connectivity are central tenets of stream hydrology and ecology. Some examples might include the Four-Dimensional Nature of Lotic Ecosystems (Ward 1989), the River Continuum Concept (Vannote et al., 1980), the Serial Discontinuity Concept (Stanford et al., 1988, Ward and Stanford 1995, Stanford and Ward 2001), and the Featured Collection of JAWRA devoted to this very topic (Nadeau and Rains 2007 and references therein; Note: The Nadeau and Rains 2007 referenced in this specific instance is different than the Nadeau and Rains 2007 referenced throughout the document and elsewhere in this review. See Additional Literature Cited below.). Doing so will accomplish two objectives: (1) make it clear from the outset that we’ve long since accepted hydrological and ecological connectivity as

fundamental tenets and (2) provide critical context for much of the remaining discussion of the specific examples (e.g., l. 2174-2175).

l. 1517-518: This sentence is redundant with the following paragraph. I suggest omitted this sentence here altogether, and relying entirely upon the following paragraph to make the point.

l. 1697-1698: Water scours channels, not sediments.

l. 1698-1701: Add “reducing channel capacity” to the list.

l. 1710-1716: Lane (1955) is an excellent way to understand and explain reach-scale flow-sediment dynamics. Because Lane (1955) is often difficult to track down, you might also cite Bull (1991), who republished the findings of Lane (1955).

l. 1977-1978: The following two comments relate to nutrient subsidies, which you mention, though not specifically by name, elsewhere in the document (e.g., l. 2174-2175). Drs. Dodds and Wipfli may also mention nutrient subsidies. Therefore, you may choose to consider the following two comments here or elsewhere in a separate paragraph dealing specifically with nutrient subsidies.

l. 1977-1978: You might consider adding a paragraph here on seasonal nitrate fluxes in Mediterranean and other similar seasonally arid environments. Such seasonal fluxes have been repeatedly observed and explained as an asynchrony between hydrological and biological processes in annual grasslands in Mediterranean and other similar seasonally arid environments (Tate et al., 1999, Holloway and Dahlgren 2001, Rains et al., 2006). Quoting from the latter: “Upland annual grasses senesce in the dry season. However, microbial activity continues, nitrogen is mineralized, and nitrate accumulates in the upland soils. Annual grasses germinate early in the wet season, but do not develop substantial biomass until the middle- to late-growing season (i.e., March–April). Thus, during the early-season storm events, there is little biological demand for nitrate and it is readily leached from the upland soils into the perched groundwater that ultimately discharges to the vernal pools. Later in the wet season, much of the nitrate in the upland soils has been flushed and the upland annual grasses are flourishing, which produces a large biological demand for the remaining nitrate. Therefore, the amount of nitrate leaching into the perched groundwater and subsequently discharging to the vernal pools decreases.”

l. 1977-1978: You might consider adding a paragraph here on alder-fixed nitrogen subsidies in wetlands and streams. For example, Shaftel et al. (2010) showed that nitrogen concentrations are correlated with alder cover in salmon-bearing headwater streams on the lower Kenai Peninsula, Alaska. We are now conducting follow up work to determine if all alder patches are created equal in this regard, or if some alder patches are better positioned to provide these subsidies.

l. 1987-2001: There is more literature on this issue that you might consider incorporating here. Triska et al. (2007) did a nice study on the transport and transformation of nitrogen as it moved from a hillslope to a headwater riparian wetland and into and down the headwater stream, with the latter being pertinent in this case. Also, Hill and Lymburner (1998) and Hill et al. (1998) did nice studies on nitrogen transformations in hyporheic zones, showing that even short, shallow, and fast flowpaths through the hyporheic zone are

sufficient to transform a large amount of the available nitrogen. These studies are all nice compliments to Alexander et al. (2000), which is already described in the document.

1.2035-2047: I've always thought of spiraling as a form of short- and long-term storage. Nutrients are essential, yet are always in motion toward the receiving water bodies (e.g., the ocean). Nutrient spiraling is a way by which those nutrients are temporarily stored, perhaps for a short time (e.g., algae), or perhaps for a long-time (e.g., trees), before being released again to downstream ecosystems. This is similar to the roles played by woody debris and floodplains in the short- and long-term storage of sediments.

1. 2398-2407: You make a good argument, but you might consider adding the importance of upstream migration. I don't know much about this, but I'm led to believe that invertebrates tend to fly upstream after emergence, all the better to recolonize upstream habitats that tend toward depopulation due to drift. I don't know if this is actually true—though it seems that it must be true—or if there is any literature on this if it is true—though I do recall being told that there is literature on this by someone knowledgeable.

1. 2486-2487: You might consider adding a paragraph here on the importance of anadromous fish in transporting nutrients, especially marine-derived nutrients, to headwater streams and associated riparian habitats. There is a good review of this in Nadeau and Rains (2007).

1. 2486-2487: You might also consider adding a paragraph here on barriers and the effects of barriers. Dynesius and Nilsson (1994) showed that 77% of the total water discharge of the 139 largest river systems in North America north of Mexico, Europe, and the former Soviet Union are fragmented by dams and/or significant water abstraction. Stanford et al. (1988), Ward and Stanford (1995), and Stanford and Ward (2001) talked about this in terms of the natural flow of mass, energy, and organisms, terming the overall effect the Serial Discontinuity Concept. And Fleckenstein et al. (2004) provided a good example of this, by showing that groundwater pumping causes a regional groundwater drawdown, which causes enhanced groundwater recharge through the streambed of the Cosumnes River, which causes the cessation of flow in Cosumnes River in the early fall, which creates a barrier to a fall-run Chinook salmon population.

**2. This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.**

- a) Are these conclusions supported by the scientific evidence?**
- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

## SUMMARY

The conclusions are supported by the scientific evidence provided. This is still a relatively easy task for the authors, because hydrological and ecological connectivity are fundamental tenets for these systems. However, I do have comments regarding some flaws and/or inadequacies in the scientific evidence provided as

justification. (See, also, the detailed comments related to the conceptual framework in the section titled “Additional Reviewer Comments” below.)

## DETAILED COMMENTS

General Comment: The classification scheme used in this document is unusual. I understand why you might want to separate this into channels, wetlands on floodplains, and wetlands not on floodplains, given the regulatory environment. However, this is not a common way to classify wetlands, which makes the document a bit hard to follow. I think that you can leave this general separation in place, but you might then explain what kinds of wetlands might be included, using an HGM classification scheme. In this way, you can explain that this chapter is dealing with all kinds of wetlands—riverine as well as flat, depressional, slope, lacustrine, and estuarine—as long as they are subject to regular or episodic flooding and therefore connection to streams.

l. 3524-3556: This entire section would be greatly strengthened if you would include a review of some of the papers that show that hydrological and ecological connectivity are central tenets of floodplain hydrology and ecology. Some examples might include the Flood Pulse Concept (Junk et al., 1989, Tockner et al., 2000) and the extension of the Serial Discontinuity Concept to floodplains (Ward and Stanford 1995). Doing so will accomplish two objectives: (1) make it clear from the outset that we’ve long since accepted hydrological and ecological connectivity as fundamental tenets and (2) provide critical context for much of the remaining discussion of the specific examples.

l. 3574-3575: You might also consider adding a paragraph here on the role that bank storage plays in supporting baseflow, especially immediately following high flows (Whiting and Pomeroy 1997, Hammersmark et al., 2008).

l. 3584-3585: Here and in a few other locations, you use the word “filter” to describe sediment removal from flowing water by riparian and floodplain wetlands. However, it isn’t a filtering effect, it’s a hydraulic effect, as water slows, loses strength (e.g., specific stream power), and deposits sediments, usually in order of mass (Meyer et al., 1995, Dabney et al., 1995). You know this to be true, because you go on to say as much later (e.g., l. 3601-3602). This is a little issue; but you’ll forgive me because it’s a pet peeve of mine.

l. 3601: Riparian areas are both sources and sinks for sediments. Riparian areas provide both short- and long-term storage locations for sediments, and can be sediment neutral, sediment sinks, or sediment sources depending upon whether the stream has reached its base profile—in which case sediment storage and mobilization balance; accommodation space has been created—in which case, sediments can be stored; or accommodation space has been destroyed—in which case, sediments can be mobilized (Quirk 1996).

l. 3609-3618: This paragraph seems out of place, in that it doesn’t seem to connect to the surrounding discussion of connectivity, but it will fit much better if you broaden the previous paragraph as suggested in my comment titled “l. 3601”.

l. 3644-3646: Groundwater does not always move through the alluvium and/or equilibrate with the temperature of alluvium. Some groundwater that discharges to riparian environments flows along regional

groundwater flowpaths, and is therefore more likely to have the temperature of the volumetric weighted average of the recharge water (Rains and Mount 2002, Kish et al., 2010).

l. 3695-3697: This paper, and a few others, have created a lot of headaches in recent years, because of sentences just like this, which imply that evapotranspiration causes water levels to rise. The paper, in my opinion, is a bit flawed, in that it misrepresents the net effect of evapotranspiration and makes a claim wholly unsubstantiated by the data. Let me deal with these issues one at a time. First, evapotranspiration causes a net decline in water levels, which will tend to move water out of the carbon-rich soils. Hydraulic lift does occur, but that only partially offsets the initial drawdown. Imagine a point just below the water table but in the carbon-rich soils. Before evapotranspiration, that point is saturated, so the pressure potential is positive. After evapotranspiration, the water table declines to below that point, so the point is unsaturated, so the pressure potential is negative. At this point, water can flow uphill, down the pressure gradient, from the water table up toward the point. (This, in fact, is the source of the well-known capillary fringe.) The point may not be saturated—in fact, in most alluvial deposits, the point will not be saturated—though it likely will be moister than in the absence of the hydraulic lift. Still, the net effect, for this point, is that it went from saturated to unsaturated, which means that less water, not more water, is in the carbon-rich soils. Second, this means that less, not more, N transformations are likely to occur. More importantly, Kellogg et al. (2008) wasn't about N transformations at all—this was just a purely speculative paragraph based upon no data that, quite frankly, the editors and reviewers at JAWRA should have asked to be removed.

l. 3702-3705: What do you mean by “redoxing agents”?

l. 3708-3734: This entire section is poorly referenced. This is nitrogen in riparian and floodplain wetlands, for which there are many studies, and yet only one study is referenced. Granted, the paper is good, and well referenced itself, but it seems like you, too, could bolster your argument with additional references, such as the roles played by riparian wetlands in reducing nitrogen loads in agricultural runoff (Peterjohn and Correll 1984), the roles played by hyporheic flows, including those at the channel-floodplain interface, in reducing nitrogen in stream waters (Dahm et al., 1998, Hill and Lymburner 1998, Hill et al., 1998), and the role that linked hillslopes-headwater wetlands-headwater streams play in reducing nitrogen loads as water flows from hillslopes to river networks (Triska et al., 2007).

l. 3835-3836: Add Tockner et al. (2000) to the references here. Junk et al. (1989) developed the flood-pulse concept for tropical rivers; Tockner et al. (2000) extended the flood-pulse concept to temperate rivers.

- 3. This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**
- a) Are these conclusions supported by the scientific evidence?**
  - b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**
  - b) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

## **SUMMARY**

The conclusions are supported by the scientific evidence provided. This is the most difficult task for the authors, because hydrological and ecological connectivity are not fundamental tenets for these systems. However, I do have comments regarding some flaws and/or inadequacies in the scientific evidence provided as justification and regarding the wording of the conclusion, which I think soft-peddles the conclusion. (See, also, the detailed comments related to the conceptual framework in the section titled “Additional Reviewer Comments” below.)

## **DETAILED COMMENTS**

1. 4004-4017: This is a confusing paragraph. At first, it seems like only depressional wetlands are going to be included, and it's not until l. 4008 and beyond that other types of wetlands are mentioned. I suggest listing all of the types as a list in the first sentence, then clarifying the details in order thereafter.
1. 4025-4098: You might consider wind transported snow as a special case of hydrological connectivity. In that regard, you might consider including Rains (2011), who showed that moraine, ice-scour, and dead-ice depressional wetlands serve as groundwater recharge focal points because aeolian-transported snow is trapped in the topographic lows in winter and then melts and recharges underlying groundwater immediately following breakup in late spring, with the net effect being that groundwater recharge rates in these depressional wetlands is 37%-332% of the broader surrounding landscape.
1. 4053-4078: You might also consider discussing the special but very important case of groundwater flow-through wetlands. Groundwater flow-through lakes and depressional wetlands, where surface waters are a surface expression of broader groundwater phenomena, have long been recognized. Born et al. (1979) and Rains (2011) described groundwater flow-through depressional wetlands in glaciated landscapes, Sloan (1972) and Richardson et al. (1992) described groundwater flow-through prairie potholes in the northern prairie, and Murphy et al. (2008) described groundwater flow-through depressional wetlands in clay-rich soils with abundant dessication cracks and other macropores. Rains et al. (2006) showed that vernal pools in central California are a special case, being groundwater flow-through wetlands supported by a seasonal perched aquifer that is unconnected to the underlying regional aquifers.

l. 4100-4116: You might consider explaining why depressional wetlands are so good at storing surface water. Though water can be stored in uplands, too, surface-water storage in wetlands is more efficient than shallow groundwater storage in uplands, because wetlands have an effective specific yield of ~1.0 (i.e., the entire empty portion of the basin is available for storage) in most circumstances (Sumner 2007), while upland deposits have a specific yield of ~0.1-0.2 (i.e., only 10-20% of the deposits are voids available for storage) in most circumstances (Johnson 1967).

l. 4145-4146: Hammersmark et al. (2008) showed that this dry-season baseflow ceased earlier when an incised river was restored to the historic floodplain. One of the reasons for this was that evapotranspiration was higher in the restored floodplain wetlands than in the previously drier floodplain uplands.

l. 4390-4398: This is the first occurrence of this list, which recurs a few times hereafter. In all cases, you should add that wetlands can be connected by groundwater connections to one another and to nearby streams.

l. 4401-4402, l. 4415-4425: I lump these specific lines together in one comment to make an important point. In the first case, you state in clear, concise, and unequivocal terms that riparian and floodplain wetlands are highly connected to river systems. In the second case, you dither for a few paragraphs, then finally get around to saying that non-riparian and channel origin wetlands might be connected to river systems under certain circumstances. You are correct; however, by dithering and then only vaguely supporting the idea that non-riparian and channel origin wetlands might be connected to river systems, and then only under certain circumstances, I think that you soft-peddle what we know about the flow of water across landscapes. To be honest, all hydrologic systems are interconnected to some degree or another—that's why hydrologists refer to the entire water cycle environment as the hydrosphere. All we're really debating here is the degree to which non-riparian and channel origin wetlands are connected to river systems. There is no bright line between connected and isolated, there is only a vague gray area where we might choose to transition from their being a significant nexus to their not being a significant nexus. This was a central point to the arguments by Nadeau and Rains (2007), and I think it's an important argument to make here, because the scientific evidence clearly supports that position.

l. 5295-5298: Vernal pools aren't really located in what most people in the West would consider "coastal areas of the western United States". For example, Rains et al. (2006, 2008) were working in the Central Valley of California, in vernal pools that were 2-3 hours drive from the coast. I think it more correct to just say "the western United States" or "Mediterranean-like climates in the western United States".

l. 5314-5318: You might consider adding Rains et al. (2006) to the references at the end of this sentence.

l. 5385-5387: You might consider adding Rains et al. (2006) to the references at the end of this sentence.

l. 5401-5412: There is a key difference between these two types of vernal pools that you have missed. The vernal pools on clay-rich soils are perched surface-water systems; the vernal pools on hardpan soils are perched surface-water and groundwater systems. This makes them behave very differently from a hydrological perspective.

Table 5-2, Table 5-3: These tables provide are concise synthesis. Can one be made for rivers?

4. **This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**
  - a) **Is this conclusion supported by the scientific evidence?**
  - b) **Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**
  - c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

## SUMMARY

To be honest, I don't see where you make this case explicitly at all. I do think that it is true, or at least that it can be true. For example, there's no doubt that obliterating a single headwater stream high up in the watershed will have no measurable effect on the large, mainstem river where it discharges to the ocean, but there's equally no doubt that obliterating all of the headwater streams in the watershed will have a measurable and catastrophic effect on the large, mainstem river where it discharges to the ocean. Justice Kennedy, in his opinion in *Rapanos v U.S.* (2006), would seem to agree. I do think that the basic pieces are in this document to make that case, but I think it important that you explicitly make this case, both throughout the document (e.g., in a paragraph or section when discussing streams, riparian and floodplain wetlands, and non-riparian and channel origin wetlands) and in a single standalone section, perhaps referencing the voluminous cumulative effects literature (e.g., Bedford and Preston 1988, Lee and Gosselink 1988, Childers and Gosselink 1990, Johnston 1994, and many others). The latter could be done toward the end of the conceptual model, after you have shown landscape-scale connectivity between all of the disparate pieces separately discussed in this document. The former could then be done with examples within the individual discussions of the disparate pieces discussed in this document. You already do some of this—for example, you do discuss the role that depressional wetlands play in storing water and reducing stormflows (l. 4100-4116)—but you probably should do more and more explicitly state the point that you are trying to make here whenever you do.

There are numerous examples of this with regards to flood storage that you could add to those that you already have discussed. Non-floodplain wetlands temporarily store surface water, thereby attenuating and translating flood peaks in downstream river networks (Haan and Johnson 1968, Hubbard and Linder 1986). This phenomenon is so well known that rainfall-runoff models typically have a step when a storm begins where rainfall is abstracted and put into depressional storage and is unavailable for runoff throughout the remaining storm (McCuen 2005). However, storage capacity is a finite quantity that can be exceeded, suggesting that flat and depressional wetlands will have the greatest effect during smaller storms (Haan and Johnson 1968). In fact, ephemeral surface-water connections occurring immediately following larger storms are an indication that storage capacity has been exceeded and subsequent water is immediately discharged (Rains et al., 2006, Rains et al., 2008).

There are also implicit examples of both flood storage and other processes that can be inferred from the literature. Depressional wetlands can focus groundwater recharge. As described elsewhere, Rains (2011) showed this to be the case for moraine, ice-scour, and dead-ice depression in southwest Alaska. He did not

specifically upscale—necessary spatial data were lacking—but he did show that these types of wetlands are perhaps the most numerous and conspicuous types of wetlands in these environments, implying that, though the individual effect of one wetland may be negligible, the cumulative effect of the many thousands of wetlands must necessarily be important. In this case, the effect is implicit, not explicit, but you could nevertheless make this point more strongly by explicitly stating this implicit assumption.

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**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands to  
Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Comments submitted by Dr. John S. Richardson**

**GENERAL COMMENTS (Technical charge comments below)**

This is a very nicely written and comprehensive document. The regulatory context is explained very well as background to understanding the intent of the report. The definitions of terms such as riparian, wetland, connection, etc., are given so that the details are explicit. The case studies approach to giving explicit examples and how their connections would be interpreted is a good idea and very effective, especially given that the examples were for systems that could be questioned about their connectedness with navigable waters, depending upon interpretation of the terms of the legal opinions. The figures are effective in illustrating principles and evidence.

The conceptual framework with source, sink, lag, transformation and refuge (Leibowitz et al., 2008) is a nice idea, and it provides a good way to educate readers about the kinds of processes, and how they are influenced by spatial scales and temporal scales. However, this framework doesn't seem to be used throughout the stream examples (chapter 4). For instance, the example from the prairie streams doesn't mention these conceptual components much. The examples given about streams provide good examples demonstrating the processes that connect the small tributaries to downstream reaches, but it would be useful to better link these with the conceptual framework. The wetland chapter (5) does a better job of bringing these model terms into the description throughout that section.

A "non-riparian" wetland (NRCWs – non-riparian and channel origin wetlands) seems an odd term, but I wonder if non-floodplain wetland might be better? The definition of riparian area as transitional between aquatic and terrestrial (P.26) makes it difficult to know when one might no longer be in transition across a floodplain, for example. Gregory et al.'s (1991) definition of riparian area would make it difficult to have a non-riparian wetland, unless this simply means not in the riparian area of a navigable-in-principle stream. The consistent use of floodplain and riparian as a combination term (e.g., L.590) makes me think that floodplain might be sufficient (later in Chapter 5 the use of "riparian/floodplain" makes them seem interchangeable). Chapter 5 appeared confusing as to whether wetlands were floodplain/riparian (P.212) or NRCWs at some points, but maybe these were to apply to all wetlands. At one point (L. 594) it says that both floodplain and NRCWs could be geographically isolated, but I am having difficulty seeing how this definition of surrounded by uplands could apply to floodplain wetlands.

It seems like the methylation of mercury is better explained on P.233 than it is earlier in the chapter when mercury is discussed for NRCWs. Perhaps the explanation could be moved up to provide the detail when it is first mentioned.

Coastal streams entering the oceans, and not a navigable-in-principle river, might not be covered under the definitions used in this report.

Some sections seem to convey a lot of information that is somewhat peripheral to the issue at hand, for instance, it is not clear what the material on P.136-137 contributes to the understanding of whether this is a navigable-in-principle stream or tributary to a navigable-in-principle stream.

It wasn't clear what the distinction between Carolina Bays and Delmarva Bays is, or whether it is solely geographic. The Glossary did not help with that.

It appeared to me that the Executive Summary was a little long, depending upon who the anticipated audience for this might be. There is a lot of territory to cover, and perhaps the regulators will need this much information. The summary is sound, so I am not criticizing the content, just the length.

I am still a bit vague on the opinion of the other 4 justices that were not included in the Scalia or Kennedy statements. I think that the other opinion(s) should be explained a little further.

I like the idea of proportional benefits from non-navigable waters, as expressed in the Leibowitz et al. (2008) paper. Moreover, the idea that these benefits may be realized or potential benefits is a helpful way to think about the capacity of a source system to provide benefit. However, these benefits may not be linear with respect to concentration or rates in their contributions. For instance, some nitrogen released to downstream would be beneficial, whereas too much would be detrimental, and the relative benefit might vary in a way that not add up so nicely.

Some authors, such as Stan Gregory (Oregon State U), are trying to discourage the use of "large woody debris" (L.1780), and in preference use "large wood" to avoid connotations of **waste** material given what we know about the important geomorphic and cover roles of large wood in streams and wetlands.

The "Draft guidance ..." document appears to be for field staff, and perhaps a decision tree or flow diagram might be useful to distinguish classes of entities and then refer from that to detailed guidance. It seems like a hefty document to plow through to determine what kind of system they are looking at. Of course, all the document is needed, but some way to sort through it quickly might be helpful.

## **Editorial**

L.3135 – change "particularly" to "particular"

L.4929 – family Chironomidae, not subfamily

## TECHNICAL CHARGE QUESTIONS

1. **This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

Yes, the conclusions are consistent with the evidence presented in the scientific, peer-reviewed literature.

**a) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

The authors provide a comprehensive suite of references to support their summary and conclusions. These references are the most relevant, and other papers that come to mind would not further enhance the understanding of the topic. One that deals with the punctuated delivery of large wood to channels and its storage and lag processes is by Swanson et al. (1998).

Swanson, F.J. et al. 1998. Flood disturbance in a forested mountain landscape - Interactions of land use and floods. *BioScience* 48:681-689.

**b) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The review provides a solid assessment of the literature and covers the evidence for connections. Yes, the conclusions are supported and appropriate literature is compiled. The authors have been careful throughout to point out any uncertainties in the conclusions that can be drawn from the available literature. The only limitation to the assertion that all streams are connected to rivers might be in the case of coastal streams not contributing to a nexus with a navigable-in-fact river, but these are still connected to streams (or estuaries) downstream.

2. **This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

This provides a very good summary of the literature and the conclusions are supported.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

The literature covered is excellent.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The interpretations of what is known and the limitations of inferences possible from the literature are fine. The authors do a very good job throughout the document of ensuring they point out the uncertainties in demonstrating significant connections. Good examples given to describe the types of wetlands and their connections to navigable rivers.

I find the use of the term riparian a little confusing. It would be hard to distinguish functionally or structurally in most cases how a floodplain differed from a riparian area, so to refer to “riparian and floodplain” wetlands seems redundant (see definition of riparian on P.26). This also goes to whether there is such a thing as a non-riparian wetland, as a wetland should generate its own riparian area. Perhaps this should be defined as a non-floodplain wetland.

**3. This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**

**a) Are these conclusions supported by the scientific evidence?**

The conclusions are supported and carefully reviewed. The connection is supported for some cases, but not for all, so I agree that one cannot categorically conclude that this class of wetlands is connected. The role of isolated wetlands in storing water that may reduce runoff intensity and storm-flow generation to streams is a good idea that deserves further study to empirically back up the simulations presented. Likewise, the contributions of these isolated wetlands on transformation and storage of nutrients, thereby preventing their transport to rivers could be another important mechanism by which these wetlands contribute to navigable rivers and deserves field trials. The uncertainties associated with the connections of non-floodplain wetlands are carefully acknowledged for the examples, especially for the example of coastal bays, which have some indications of connections, but not strong, and the authors are careful to address that. The prairie potholes likewise occupy a continuum, but most have evidence of some connection. The distinction made to clarify geographic isolation from functional connectivity is useful.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

The literature reviewed is excellent and represents state-of-the-science.

- c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The summary of the literature is very good and the authors have appropriately represented the collective evidence.

4. **This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**

- a) **Is this conclusion supported by the scientific evidence?**

Given the preponderance of small streams and wetlands that are not navigable in and of themselves, they in aggregate do contribute enormously to navigable systems. The conclusions drawn by the authors are sound and well supported by the literature.

- b) **Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**

The review has covered a comprehensive set of literature relevant to the topic.

- c) **Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The authors have made a very thorough search of the literature for appropriate references and have drawn appropriate conclusions, including pointing out any uncertainties about the conclusions possible.

### **Post-meeting comments**

It seems that there is a need to go beyond connectivity, to include aspects of the effects downstream. This was made clearer during the meeting. It also clarified why there were sections of the charge questions that seemed more about the aggregate effects downstream, particularly question #4. This topic is not well covered in the report, and a separate section on downstream effects would be warranted. The connectivity aspects do not try to address the magnitudes of effect sizes. Along with the discussion of effects, the nature of those effects, and especially cumulative effects, needs to be elaborated. After the fact, I realized that the title “Connectivity...” in the report and all the workshop documentation led me to focus on the connections and not the effects. Given that the 1<sup>st</sup>, 2<sup>nd</sup> and 4<sup>th</sup> charge questions seem to be about consequences downstream, perhaps that should be better reflected in the title. It would certainly have drawn our attention more specifically to the quantification of effects.

As discussed in the meeting on the 30<sup>th</sup> January, the confusion over floodplain versus riparian needs to be clarified. Likewise, the category of non-floodplain wetlands needs more refinement as it covers an enormous range of wetland types. I think that if “floodplain” equals “riparian” in this scheme, then the use of floodplain should suffice. I found the use of “riparian” was not in line with what I consider to be riparian, but then it needs defining either way.

The executive summary needs to be shortened. As currently written it is rather long. I cannot determine who would read such a long summary. I know the document is intended for a broad readership, but perhaps a single page for the executive summary, and then the synthesis in the end of the document might cover all the rest of what is currently in the executive summary.

A brief section outlining uncertainties would be helpful. Perhaps that could go into an expanded chapter 6. This could provide a useful focal point for research to be done, or simply to provide an alert as to what we have less confidence in saying as a scientific community. It is reasonable to acknowledge that there remain uncertainties around the science.

The final section should be a synthesis and have some declarative statements, such as are included in the charge questions. The current 6 pages of chapter 6 seems insufficient compared to the enormous detail of the remainder of the document.

Here are some additional references, from those that address spatially structured populations of amphibians in wetlands, to papers about effects from streams to estuaries, resource subsidies, and large-scale transformations of carbon along freshwater networks. The Naiman et al. (2000) reference includes the curves from the FEMAT (1993) exercise showing how different functions link up riparian areas with water.

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**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands to  
Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Comments submitted by Dr. Joel W. Snodgrass**

- 1. This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

Yes, the scientific evidence clearly indicates a significant influence of physical and biological processes in streams having a large influence on downstream rivers. Streams provide significant amounts of materials (including nutrients, pollutants, sediments, and water) and organisms and control their temporal dynamics and rates of delivery to river systems.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity and isolation? If not please indicate which references are missing.**

Although the report is focused on influences that move from upstream to downstream (as is clearly stated in the report), some degree of isolation of headwater streams is important for the biological integrity of these habitats. For example, some species of stream-side salamanders are headwater specialist, which are only found in large numbers in headwater streams (Snodgrass et al., 2007; Peterman et al., 2009). Headwater specialists often have adaptations that allow them to cope with desiccating conditions that limited the development of predator populations (Meyer et al., 2007). Many insects as well as other invertebrate taxa are also endemic to headwater streams (e.g., Dieterich and Anderson, 2000; Fend and Brinkhurst, 2000; Fend and Gustafson, 2001). Therefore, protection of the isolated nature of headwater streams is also an important component of protecting the biodiversity associated with our nation's waters. The authors do acknowledge these ideas (see lines 906-907; 1020-1022), but I feel they are also important for managers and policy maker to appreciate. If the main focus of the report is the emphasis of effects on downstream waters, then more detailed treatment of the influence of connectivity on upstream headwaters and wetlands may not be warranted.

Although not crucial to demonstrating the influence of headwater streams for downstream rivers, in the sake of being complete it is probably worth noting the role of beavers in the functioning and influence of headwaters on downstream rivers. Beavers can dam extensive lengths of moderate to low gradient headwater streams (e.g., Snodgrass 1997), greatly altering their hydrology and geomorphology (Pollock et al., 2003; Butler and Malanson, 2005) and provide habitat for numerous organisms (e.g., Snodgrass and Meffe 1996; Stevens et al., 2006). These hydrological and geomorphological changes have large impacts on ecosystem function (Naiman et al., 1996) including greatly increased rates of denitrification (Naiman et al., 1994). Additionally, beaver ponds can be areas of high rates of mercury methylation (Roy et al., 2009). These points relate to the idea of headwater streams being places of lag and

transformation. This material should be added as the wetlands that beavers form would fall into the floodplain/riparian category of wetlands.

When the authors discuss mapping issues for headwater streams (lines 1519-1530) they should include the Brooks and Calhoun (2011) reference; they might even include some numbers from this publication. Specifically, Brooks and Calhoun (2011) estimate that 21% of 400.3 km of stream did not show up as blue lines on 1:25,000 scale USGS topographic maps. There is also the issue of channels that were formed under past land use scenarios that currently do not ever hold flowing water. Although the definition of “stream” includes flowing water (lines 503-504) later the authors suggest that headwater stream originate at where “runoff is sufficiently concentrated to erode a definable channel” (line 518). Some clarification should be included to make it clear that there are two components to a stream: flow at some time during the year and the formation of a channel.

On lines 3399 through 3413 the authors summarize the effects of altered flow regimes on invasiveness of native communities. Meffe (1984) should probably be cited here as this is one of the original, if not the original, documentation of the influence of natural flow regimes on co-existence of native and introduced fish species. Additionally, the bullet on line 3434 should include the prevention and/or mitigation of the effects of invasion by introduced species. Again, this is a place to integrate the balance between lag and source and how their alteration can impact downstream rivers.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

In general, the literature interpretation is correct and the literature cited extensive. I have only a few minor comments here. On lines 2412 through 2414 the authors suggest that most fishes utilizing headwaters can also be found further downstream and cite Horitz (1978). This may be true for more species poor assemblages, but in more species rich areas it is common to find species of fish confined to headwater streams. See discussion above for references. This change should be made in the final document.

**2. This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

On lines 233 and 234 the authors suggest that riparian buffer zones are one of the most effective tools for mitigating non-point source pollutants. This is true for non-point source pollutants such as nutrients and sediments that might enter riparian areas in groundwater and runoff, but may not be true for other pollutants such as road salts and organic compounds. I think we need to be careful of promoting riparian areas as a cure for all ills while still clearly indicating where they are useful. Given the length of the document and its focus on downstream effects the author may not need to address this comment in their final edits.

- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity and isolation? If not please indicate which references are missing.**

To the best of my knowledge in this area the report does include the most relevant literature. However, this is not my area of expertise as I have conducted little work in floodplain systems.

- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

To the best of my knowledge in this area the report does correctly interpret and cite the literature. However, this is not my area of expertise as I have conducted little work in floodplain systems.

- 3. This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**

- a) Are these conclusions supported by the scientific evidence?**

The authors use the indirect argument that headwater streams are widespread and high rates of a number of ecological processes have been measured; therefore, these systems must have an impact on downstream rivers. In fact, this is a general approach that is well founded (lines 450 through 452). However, in places the authors indicate both pieces of this argument are in place for geographically isolated wetlands—high rates of nutrient removal and extensive coverage of geographically isolated wetlands—but then only report that the effects of this removal are not reported for downstream waters (see lines 313 through 328). Although conclusion number 4 below begins to address this issue, I think the argument could be made more forcefully. In fact, what we know about the effects of impervious surface (only mentioned briefly on line 1360) makes a strong argument for a large impact of wetland loss in any watershed where wetlands cover a relatively large area—if 25% of a watershed is covered in wetlands and those wetlands are converted to impervious (or less pervious) surfaces then there will be large impacts on streams, stream hydrology, geomorphology, ecosystem function, and biological communities, ultimately affecting downstream rivers (Paul and Meyer, 2001; Welsh et al., 2005). The same argument for agricultural systems can be found on lines 1394 through 1400. Given that the depressions that form these wetlands are areas of low or no surface runoff, a principle we have put to use in our design and management of stormwater runoff using stormwater management ponds, it is highly likely that losses of geographically isolated wetlands have a disproportionately large influence on downstream waters compared to upland habitat loss. Therefore, it seems that in many areas (e.g., Atlantic and Gulf Coastal Plains) the indirect argument for connection and influence of geographically isolated (but not hydrologically isolated) wetland to downstream streams and rivers is stronger than the authors indicate with this conclusion. See my general post meeting comments for further discussion of this issue.

The authors discuss “isolated wetlands that have no hydrological connection to other water bodies” (lines 351 and 352) in a number of places in the manuscript. I am not aware of a hydrological study of an isolated wetland that has not shown some degree of connection to ground waters (either through recharge or discharge and recharge). If such studies exist it might be a good idea to give an example and indicate the number of studies that have found no connection. Additionally, lines 1206 through 1209 describe geographically isolated wetlands that recharge deep ground water or that occur in isolated terminal basins where “evapotranspiration is the only form of water loss.” I am not familiar with these systems as I work in areas where extensive shallow groundwater connections are common. There is no citation with these descriptions either. It would be nice to describe how many studies fit these descriptions and if they are limited to desert springs and lake systems such as the Great Salt Lake. Figure 3-18 makes it seem like these systems can be small and similar to geographically isolated wetlands.

Also related to the above comments, in the case study of Carolina bays the authors suggest that groundwater and surface water connections of bays to streams are still debated. However, all of the studies to date have documented groundwater connections and the loss and recolonization of these systems by fishes suggests frequent surface water connections for bays up to 700 m from intermittent streams (see Snodgrass et al., 1996 and summary argument in Sharitz 2003). Given these considerations it appears that for Carolina bays at least, connectivity is the norm and isolation rare.

On lines 3521 through 3522 the authors indicate that they “consider any evidence of connectivity with a stream to be evidence of connectivity with the river and other downstream waters.” Later (on lines 4097-4098) the authors indicate wetlands that feed losing streams cannot be considered channel wetlands. However, in the previous chapter the authors argue that losing streams should be considered connected to more permanently flowing downstream waters.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity and isolation? If not please indicate which references are missing.**

The issues discussed above concerning the importance of isolation for headwater stream communities also applies to geographically isolated wetlands. As the authors clearly review, isolated wetlands are periodically connected by surface waters to downstream areas that may provide sources of colonist that establish populations in wetlands. These populations can have large effects on wetland communities through predation, and trade-offs among the competing demands of surviving desiccating conditions and predation pressures creates adaptations to narrow ranges of hydrological and predator community conditions (Wiggins et al., 1980; Wellborn et al., 1996). Therefore, alteration of the isolation or connection of wetlands to downstream communities has the potential to alter biodiversity associated with isolated wetlands. See Snodgrass et al. (2000) for further discussion in relationship to wetland regulations.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

The literature that was reviewed appears to be interpreted correctly and cited appropriately.

- 4. This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**

**a) Is this conclusion supported by the scientific evidence?**

Yes the report clearly supports the idea that some wetlands and streams (if not all) make substantial contributions to the structure and functioning of downstream waters.

**b) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**

Yes, if the references mention above are included.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Yes, again with the consideration of comments included above.

**Minor notes and typos:**

Lines 794-794: should also include connection of floodplain wetlands to each other as a critical function of overbank flow. Many species are found associated only with floodplain wetlands and depend on overbank flows to connect floodplain wetlands for dispersal.

Line 826: delete “has”—should be “This water can alter geomorphology...”

Line 900: replace colon with period.

Line 998: add “is”—should be “...the entire river system is difficult.”

Lines 1445-1453: this paragraph describes a study, but does not report the findings, leaving the reader wondering about the importance of the study.

Lines 1458-1459: given the sheer number of potholes and other types of geographically isolated wetlands it is unlikely we will ever know conditions at even a moderate fraction of these systems. Does this mean we cannot draw any conclusions regarding these systems?

Line 1646: no paragraph needed here

Line 1677: delete “s” from “recharges”—should be “...ephemeral streams recharge groundwater...”  
Lines 2066-2067: tighten—for example, “Mulholland et al. (2008) estimated that small streams ...”

Lines 3933-3934: revise to read “... when connections between wetlands and surface waters are present.”

Lines 2347-2348: flow—“... Los Alamos Canyon resulting from untreated discharge, and less than 2% ...”

Line 7040: no volume number for this reference.

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### Post-Meeting Comments

As a general comment concerning the conceptual model introduced at the beginning of the document I think it would be a good idea to introduce both dimensions of time and space and link them to the ideas of sources, sinks, refuges, lags, and transformation. What we really have is a hill-slope to downstream river gradient where things that at the very top of a watershed (i.e., streams and wetlands) are more distantly removed from larger rivers downstream. In a sense the isolation of these headwaters and wetlands in the top of the watershed makes them sites of significant lag (e.g., water storage) and therefore potential transformation (could also be thought of as reduced spiraling length if the concept is applied to the entire gradient). Because streams and wetlands are most spatially removed from larger rivers, their individual effects will be relatively smaller and take longer periods of time to measure. However, the cumulative effect of their loss will be greater than closer streams and wetlands over the long-term. These connections between scales of time, space and the impacts of disturbance are discussed extensively in Delcourt et al. (1983). The development of the conceptual model in this way would allow the logical extension of the review to include the arguments presented earlier on the impacts of impervious surfaces and agricultural land conversion discussed in my original comments.

On a related note to the development of the conceptual view, some changes to table 3-1 would help with clarity. I do like the idea of not having a specific sequence of wetland, stream, and river. Yes, larger rivers are usually downstream (but may not be when rivers enter deserts), but wetlands and streams can occur in a sequence or be close to or relatively far removed from large rivers. The examples I would cite here are adventitious streams verse true headwater streams (See Osborn and Wiley's work that you currently cite) and channel wetlands along stream corridors (see Webster et al., 1996; Kratz et al., 1997; Magnuson et al., 1998; Baines et al., 2000; Riera et al., 2000; Webster et al., 2000 for an example in Wisconsin lakes, which are formed in the same way pothole wetlands are formed). Soranno et al. (1999) also argues for the connection between wetlands, lakes and streams based on water chemistry in these same systems. Despite the intentions of the authors' use of arrow in table 3-1, the arrows should be removed as they give the impression of an upstream/downstream gradient.

As far as the question concerning terminology for “geographically isolated wetlands,” it might be best to focus the terminology on the hill slope-downstream river gradient. Channel origin wetlands should really be considered floodplain wetlands, as they are directly adjacent to a stream. The definition of floodplain wetlands would be those wetlands that occur on the floodplain of river systems (as defined by hydrology) or located within or directly adjacent to stream channels or lakes. By the way, the lake situation is completely ignored in the document. This group of wetlands would then include beaver ponds, channel origin wetlands, and wetlands and small lakes situated along stream channel (not necessarily acting as an origin of the channel). This would be more inclusive. Then you could have hill-slope wetlands replace the non-floodplain channel origin group. Hill-slope wetlands are wetlands that are not located directly adjacent to streams and lakes or on the floodplains of rivers. This would still be a very diverse group of wetlands with a range of connectivity, but would be much less confusing. I think the intent is to convey the idea that for some hill-slope wetlands we do know something about connectivity, but for other we do not.

Finally, Catherine Pringle’s work in tropical streams provides another example of the influence of connectivity of low-land rivers to headwater streams on community production and structure, which should transfer into altered downstream influences (although I don’t think here work measured this specifically). References are Pringle et al., 1993, 1999; Pringle and Blake, 1994; Pringle, 1996; Crowl et al., 2001; March et al., 2001, 2002.

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**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands to Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Comments submitted by Dr. Arnold van der Valk**

This report does a very good job of reviewing the massive literature on the linkages between streams and wetlands and rivers. It does a particularly good job at demonstrating the linkages between streams and rivers and between wetlands on floodplains and rivers. It does less well in dealing with “isolated” wetlands. In large part this is due to lumping all kinds of non-riparian/non-floodplain wetlands into one category, Non-Riparian and Channel Origin Wetlands.

- 1. This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

Yes. Although I am not a hydrologist or stream ecologist, this is clearly demonstrated in the literature cited.

- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

Again, I am not a hydrologist, this review, however, cites a large number of relevant references to document the connectivity of streams to rivers. I doubt that any additional references would in any way alter the conclusions drawn.

- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

I am not an expert on hydrology, but I did not find any obvious problems with literature citations or with the interpretations of the literature.

- 2. This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

Yes. The multiple connections (surface water, groundwater, biological) between rivers and floodplain wetlands were well documented.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

The relevant literature on floodplains is huge and unequivocal about the connectivity of rivers and their floodplains. Although this review does not cite some relevant literature on floodplain development (e.g., J. S. Bridge. 2003. Rivers and Floodplains: Forms, Processes, and Sedimentary Record. Blackwell), it cites the most relevant reviews on connectivity between rivers and floodplains like Amoros and Bornette (2002). Again, I doubt that the conclusions drawn from the literature reviewed would be affected in any way because some relevant references were not included.

Some relevant papers from outside NA that are missing include:

Boschilia, S.M., E.F. Oliveira, and S.M. Thomaz. 2008. Do aquatic macrophytes co-occur randomly? An analysis of null models in a tropical floodplain. *Oecologia* 156: 203-214.

Henry, C.P., C. Amoros, and N. Roset. 2002. Restoration ecology of riverine wetlands: a 5-year post-operation survey on the Rhone River, France. *Ecological Engineering* 18: 543-554.

Paillex, A., S. Doledec, E. Castella, and S. Merigoux. 2009. Large river floodplain restoration: predicting species richness and trait responses to the restoration of hydrological connectivity. *Journal of Applied Ecology* 46: 250-258.

Vervuren, P.J.A., C.W.P.M Blom and H. de Kroon. 2003. Extreme flooding events on the Rhine and the survival and distribution of riparian plant species. *Journal of Ecology* 91: 135-146.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

I am not an expert on riverine hydrology, but I did not find any obvious problems with literature citations or with the interpretations of the literature.

**3. This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**

**a) Are these conclusions supported by the scientific evidence?**

Yes. This category of wetlands, however, contains a mix of wetland types that is so broad and heterogeneous that no definitive conclusions about their hydrological connectivity to rivers could ever be drawn for the entire category. There are situations where a case for hydrologic connectivity of wetlands in this class to rivers can be made using soils data, e.g., prairie potholes in Iowa. Although definitive data are missing in most cases, it can be inferred that these types of wetlands are connected biologically to rivers and vice versa in many, if not all, cases.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

Yes. It does a good job of reviewing the published literature. However, it is somewhat ambivalent about the interpretation of some of the literature on “clusters” of wetlands. Although wetlands within a cluster evidently are linked, presumably by groundwater flows, they are considered only linked if there is a surface water connection from one wetland in the cluster to a river. The potential for groundwater connections between isolated wetlands and rivers is never examined. That wetlands like prairie potholes are connected by groundwater flows is well documented. That similar groundwater flows can also connect them to rivers is at least highly probable for some prairie potholes in less hummocky terrain.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Yes. However, the use of soil maps, however, to demonstrate ephemeral surface water linkages between isolated wetlands like prairie potholes and streams is not fully explored. See above. Likewise the possible connection of isolated wetlands to rivers by groundwater flow is largely ignored.

**4. This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**

**a) Is this conclusion supported by the scientific evidence?**

For streams, this conclusion is self-evident and is supported by the literature. For isolated wetland complexes, there are only a few relevant studies. Consequently, although it may be true, it is more of a conjecture than a fact. What exactly constitutes “a cluster of small wetlands”? How do you draw the boundaries around a cluster? See above.

**b) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**

Yes, the most relevant literature has been reviewed in the report. However, the relevant literature on wetland soils that demonstrates how connected some putatively isolated wetlands like prairie potholes really are is not adequately explored. See Miller et al. (2012) in Wetland Ecology and Management.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Yes. The problem is not with the interpretation of the literature but with creating an artificial category of wetlands that contains so many different kinds of wetlands that no general conclusion could ever be drawn for the entire category.

## **Some Additional Comments**

The main purpose of this report is to demonstrate the connectivity between streams and wetlands and navigable rivers. There are a large number of papers that have been published in the landscape ecology literature on connectivity and how to measure it. This literature is largely ignored in this report. A review of what is meant by connectivity and the various relevant ways in which streams and wetlands may be linked to rivers is needed. In fact, the whole report might have been more usefully organized around various kinds of linkages with chapters on surface water flows, groundwater flows, wind, and various animal vectors and their relative influences on navigable rivers. One of the major dilemmas facing the reviewers was that hydrological linkages are better studied and thus are much easier to demonstrate than biological linkages. Not surprisingly the report emphasizes hydrological connectivity. Biological linkages are often sporadic and highly species specific and are thus harder to document. Most of the focus on biological connectivity in the report is on fish movements into and out of wetlands on floodplains. Because isolated wetlands are linked to rivers primarily by biological linkages, I believe that this report seriously underestimates the connectivity between isolated wetlands and rivers. The literature on waterbird (ducks, geese, cranes, etc.) migratory and local movements, which is largely ignored in the report, is full of accounts of birds moving from wetlands to rivers and vice versa, e.g., Canvasbacks in the Mississippi River flyway. In the case study on prairie potholes, however, there is a good synthesis of the evidence for both hydrological and biological connectivity of potholes to rivers. In short, I think that a stronger case can be made that some of the wetlands in the isolated wetland category are connected to rivers.

I found the Non-Riparian and Channel Origin (NRCW) class of wetlands created in this report unnecessary and confusing. In fact, the term NRCW is never used in the Executive Summary. For the most part, this term is used a catchall for non-riparian/non-floodplain wetlands. The common denominator that supposedly justifies putting prairie potholes and other isolated wetlands in the same class as wetlands that are the headwaters for streams (channel origin wetlands) is unidirectional surface flow (P. 42, ll. 813-815). Although some isolated wetlands like prairie potholes during high water events do have temporary surface connections to each other and even to nearby streams, many do not as noted. Many headwater wetlands, however, can have water backing up into them from streams during flooding events. It would be simpler to eliminate the use of the NRCW class from the report. The problem with lumping these two types of wetlands together is illustrated on P. 206 ll. 4292-4294: “NRCWs, however, are generally farther from stream channels than riparian/floodplain wetlands, which make hydrologic connectivity much less frequent, if present at all.” This statement is by definition untrue for channel origin wetlands.

Instead of the artificial NRCW class of wetlands, it would be more useful to follow the Cowardin et al. (1979) classification of wetlands which distinguishes five basic types (systems) of wetlands, only three of which are relevant in this context, (riverine, palustrine, and lacustrine). As defined by Cowardin et al. (1979), “The term SYSTEM refers here to a complex of wetlands and deepwater habitats that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors.” Cowardin et al., recognize that intermittent streams are connected to perennial reaches of streams. They are treated as part of the riverine system. Lacustrine wetlands are found along the peripheries of lakes, and there is absolutely no doubt that they are connected to navigable water. What is being examined in this report is the connectivity between rivers and various kinds of palustrine wetlands. Palustrine wetlands are bounded by uplands. There are many kinds of palustrine wetlands, and they are found “shoreward of lakes, river channels, or estuaries; on river floodplains;

in isolated catchments; or on slopes.” In other words, this report should focus on the connectivity of different kinds of palustrine wetlands. This ranges from those clearly linked to rivers like palustrine wetlands on floodplains to those with much weaker linkages like palustrine wetlands in isolated catchments like many inter-mountain wetlands. In the case of palustrine wetlands that generally have no surface water connections to rivers, each major type should be treated separately (prairie potholes, California vernal pools, Carolina bays, Texas playas, etc.)

The Cowardin et al., classification systems is used by the National Wetland Inventory. Discussing the connectivity of palustrine wetlands to rivers would make it immediately obvious to readers familiar with wetlands what this report is trying to do, and it would link the report more directly to the existing wetland literature.

Five functions of streams and wetlands are recognized (P. 5, ll. 106-113). I would suggest renaming the last one, Lag, Desynchronization. A lag is an effect, not a function.

What is the relative importance of hydrological vs. biological connectivity? It is possible for some types of wetlands to have no surface water connection to streams. Given that all wetlands have hydric plants and a host of aquatic animals (invertebrates, birds, mammals, microorganisms, etc.), even hydrologically isolated wetlands are never isolated biologically. What species should count in establishing biological connectivity? In the report, all microorganisms (algae, bacteria, fungi, protozoans, etc.) are essentially ignored. Although the report does a good job in demonstrating the ubiquity of biological connectivity, it is unclear how important this type of connectivity is when compared to hydrological connectivity and what minimum criterion or threshold is required to demonstrate biological connectivity. Does demonstrating the one-time movement or dispersal of one species from a river or a stream to a hydrologically isolated wetland (or vice versa) mean that the “isolated” wetland is not really isolated? If just establishing some kind of biological linkage between a wetland and a river establishes connectivity, then there is no such thing as an isolated wetland.

When looking for linkages between “isolated” wetlands and rivers, a landscape approach is needed. One possible way to examine these linkages would be to use an HGM approach to estimate water, sediment, nutrient, etc. storage by the wetlands in a watershed and thus not entering the rivers. Potential linkages of various animal groups and wind could also be explored using this general approach. The more linkages that can be demonstrated the greater the influence of isolated wetlands in a watershed (or other comparable landscape unit) on the rivers in it.

In summary, the authors of the report focus primarily on surface water flows as the major link between rivers and streams and wetlands. This primarily unidirectional flow of water into rivers is easy to demonstrate and its importance can be quantified. The more complex and often sporadic and bidirectional linkages caused by wind and movement of organisms are noted, but their influence on navigable waters has rarely been documented. Whether such movements are essential for the persistence of some organisms in rivers is unknown. That some organisms (some waterfowl, some mammals, some amphibians) use both rivers and isolated wetlands during their life cycles is known. As a consequence, in any landscape all bodies of water are interconnected and influence each other, but these interactions are often sporadic and asymmetrical.



## **Mark S. Wipfli, Ph.D.**

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Fairbanks, AK

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Education -- Ph.D., 1992, Michigan State University, Aquatic Ecology & Environmental Toxicology; M.Sc., 1987, University of Wisconsin Madison, Entomology; B.Sc., 1984, University of Wisconsin Madison, Natural Science

Dr. Wipfli's research interests include understanding:

- Trophic linkages between headwaters and downstream habitats
- Trophic processes that govern freshwater-riparian productivity
- Spatial subsidies in freshwater food webs
- Linkages between freshwater-marine and freshwater-terrestrial ecosystems
- Salmonid foraging ecology and trophic interactions
- Invasive species impacts in freshwater/riparian ecosystems
- Climate change effects on freshwater food webs
- Restoration and management of freshwater and riparian ecosystems

He has published in Canadian Journal of Fisheries and Aquatic Sciences, Transactions of the American Fisheries Society, North American Benthological Society, Freshwater Biology, Hydrobiologia, Oecologia, BioScience, Fisheries, and others

Selected publications relevant to the workshop:

Wipfli, M.S., and C.V. Baxter. 2010. Linking ecosystems, food webs, and fish production: Subsidies in salmonid watersheds. *Fisheries* 35(8): 373-387.

Binckley, C., M.S. Wipfli, R.B. Medhurst, K. Polivka, P. Hessburg, B. Salter, and J.Y. Kill. 2010. Ecoregion and land-use influence invertebrate and detritus transport from headwater streams. *Freshwater Biology* 55: 1205-1218.

Medhurst, R.B., M.S. Wipfli, K. Polivka, C. Binckley, P. Hessburg, and B. Salter. 2010. Headwater streams and forest management: Does ecoregional context influence logging effects on benthic communities? *Hydrobiologia* 641: 71-83.

Wipfli, M.S., J.S. Richardson, and R.J. Naiman. 2007. Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates, and wood down headwater channels. *Journal of the American Water Resources Association* 43: 72-85.

Gomi, T., A.C. Johnson, R.L. Deal, P.E. Hennon, E.H. Orlikowska, and M.S. Wipfli. 2006. Factors affecting distribution of wood, detritus, and sediment in headwater streams draining managed young-growth red alder-conifer forests in Southeast Alaska. *Canadian Journal of Forest Research* 36: 725-737.

- Hernandez, O., R.W. Merritt, and M.S. Wipfli. 2005. Benthic invertebrate community structure in headwater streams is influenced by forest succession after clearcut logging in southeastern Alaska. *Hydrobiologia*. 533: 45-59.
- Wipfli, M.S. and J. Musslewhite. 2004. Density of red alder (*Alnus rubra*) in headwaters influences invertebrate and organic matter subsidies to downstream fish habitats in Alaska. *Hydrobiologia*. 520: 153-163.
- Piccolo, J.J., and M.S. Wipfli. 2002. Does red alder (*Alnus rubra*) along headwater streams increase the export of invertebrates and detritus from headwaters to fish-bearing habitats in southeastern Alaska? *Canadian Journal of Fisheries and Aquatic Sciences*. 59: 503-513.
- Wipfli, M.S., and D.P. Gregovich. 2002. Export of invertebrates and detritus from fishless headwater streams in southeastern Alaska: implications for downstream salmonid production. *Freshwater Biology*. 47: 957-969.

**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands to Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Comments submitted by Dr. Mark S. Wipfli**

- 1. This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

Yes, to the best of my knowledge, the conclusions are fully supported by the evidence in the scientific literature. There is strong evidence in the scientific literature that headwaters are physically, biologically, and chemically connected to, and influence, downstream waters and associated biota. The evidence reported and cited in this review is presented accurately, thoroughly, and clearly.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

Yes, to the best of my knowledge, the report includes a broad, relevant literature on the connections between headwaters and downstream freshwater ecosystems. However, I did not see literature discussed and cited that addresses the linkages between headwaters and estuaries and oceans, even though that point is stated in the first paragraph of “Background” section of “Technical Charge to External Peer Reviews” document. Should this be included?

Five additional references from my headwaters work on biological linkages that may be helpful are listed below. The latter four deal with management effects on headwater streams.

Wipfli, M.S., and C.V. Baxter. 2010. Linking ecosystems, food webs, and fish production: Subsidies in salmonid watersheds. *Fisheries* 35(8): 373-387. *This paper takes a broader look at watersheds, putting into context the biological connections between headwaters, river networks, riparian habitats, and the ocean.*

Binckley, C., M.S. Wipfli, R.B. Medhurst, K. Polivka, P. Hessburg, B. Salter, and J.Y. Kill. 2010. Ecoregion and land-use influence invertebrate and detritus transport from headwater streams. *Freshwater Biology* 55: 1205-1218. *This paper shows how past timber harvesting affects invertebrate flow from headwaters to downstream habitats.*

Medhurst, R.B., M.S. Wipfli, K. Polivka, C. Binckley, P. Hessburg, and B. Salter. 2010. Headwater streams and forest management: Does ecoregional context influence logging effects on benthic communities? *Hydrobiologia* 641: 71-83. *Addresses past timber harvest effects on headwater stream invertebrate communities.*

Wipfli, M.S. and J. Musslewhite. 2004. Density of red alder (*Alnus rubra*) in headwaters influences invertebrate and organic matter subsidies to downstream fish habitats in Alaska. *Hydrobiologia*. 520: 153-163. *This paper showed that headwater streams also supply terrestrial invertebrates to downstream waters, in addition to aquatic invertebrates, and illustrated how riparian management affects biological connections between riparian areas, headwater streams, and downstream waters.*

Piccolo, J.J., and M.S. Wipfli. 2002. Does red alder (*Alnus rubra*) along headwater streams increase the export of invertebrates and detritus from headwaters to fish-bearing habitats in southeastern Alaska? *Canadian Journal of Fisheries and Aquatic Sciences*. 59: 503-513. *This paper looks at how riparian regrowth following timber harvest in Alaska affects transport of aquatic invertebrates to downstream waters.*

Another paper from research we conducted on headwater streams looking at the role of wildfire in affecting linkages between headwater streams and downstream waters, via the flow of invertebrates downstream:

Mellon, C.D., M.S. Wipfli, and J.L. Li. 2008. Effects of forest fire on headwater stream macroinvertebrate communities in eastern Washington, USA. *Freshwater Biology* 53: 2331–2343.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Yes, the literature in this report was cited and summarized accurately. The authors provided a very clear and thorough illustration of the demonstrated linkages that connect headwaters to downstream waterways.

A few points that might help:

Line 1494 – “and associated biota” at the end of the sentence?

Lines 1698, 1709, 1844 – Several places in the text (these two as examples) could benefit with a relevant citation.

Lines 1793-4 and 1804-6 seem to be in conflict with each other.

Line 2160 – space before 100.

Line 2375 (whole section) – this would be a good place to discuss the role of terrestrial invertebrates that enter headwaters, and in turn get transported downstream from headwaters (Wipfli and Musslewhite 2004). Not sure if the authors would like to have this concept in the report, but it also ties in human impacts into the story.

2. **This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.**

**a) Are these conclusions supported by the scientific evidence?**

Yes, to the best of my knowledge, the conclusions are fully supported by the evidence in the scientific literature. There is strong evidence in the scientific literature that riparian area wetlands and other waters are physically, biologically, and chemically connected to, and influence, the river network. The evidence reported and cited in this review is presented accurately, thoroughly, and clearly.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

Yes, the report appears to include the most relevant literature that shows how off-channel freshwater habitats are connected to mainstem channels and riverine networks.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Yes, the literature in this report was cited and summarized thoroughly and correctly.

3. **This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.**

**a) Are these conclusions supported by the scientific evidence?**

Question is outside my area of expertise.

**b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.**

Question is outside my area of expertise.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Question is outside my area of expertise.

- 4. This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.**

**a) Is this conclusion supported by the scientific evidence?**

Absolutely yes. This is a key point about headwaters and downstream waterways that unfortunately can easily be overlooked, and I was pleased to see this addressed. Individually, small streams do generally not have large influences by themselves on downstream processes, but in aggregate they tremendously affect riverine networks at the watershed scale.

**b) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.**

Yes, the report includes the relevant scientific literature on the cumulative effects of headwaters.

**c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.**

Yes, to the best of my knowledge the literature on this topic was cited and summarized thoroughly and correctly.

**Marine-derived nutrient effects on stream productivity**

Discussed at the review on 30 Jan, 2012 was the topic of marine-derived nutrients, and their effects on headwater productivity in places that receive runs of anadromous fishes. It was suggested that a discussion of this topic be included in the report, and I agree that it should be included. This phenomenon is demonstrated through runs of adult Pacific salmon throughout the west coast of North America, but occurs along the east coast with Atlantic salmon, as well as runs of shad, lamprey, and other species, and throughout other parts of the world. Spawning adults deliver nutrients and carbon from the ocean when they return to fresh water to spawn (and die). This subsidy of nutrients and carbon (energy) from the ocean has been universally shown to increase stream productivity, including in headwater streams, at multiple trophic levels (periphyton, aquatic invertebrates, and fishes). The increased production in headwaters in turn provides more invertebrates that can get flushed downstream from smaller headwater channels to downstream waters. Thus, the ocean is connected to headwaters via the movement of marine subsidies into watersheds. In turn a portion of this invertebrate production can subsequently get delivered downstream from headwaters.

Here are some of my papers on this topic. They in turn contain numerous additional citations on the subject that can be included in the report, if EPA decides this is a topic worth including.

Wipfli, M.S., J.P. Hudson, J.P. Caouette, N.L. Mitchell, J.L. Lessard, R.A. Heintz, and D.T. Chaloner. 2010. Salmon carcasses increase stream productivity more than inorganic fertilizer pellets: A test on multiple trophic levels in streamside experimental channels. *Transactions of the American Fisheries Society* 139: 824-839.

- Heintz, R.A., M.S. Wipfli, and J.P. Hudson. 2010. Identification of marine-derived lipids in juvenile coho salmon and aquatic insects through fatty acid analysis. *Transactions of the American Fisheries Society* 139: 840-854.
- Lang, D.W., G.H. Reeves, D.D. Hall, and M.S. Wipfli. 2006. The influence of fall-spawning coho salmon (*Oncorhynchus kisutch*) on growth and production of juvenile coho salmon rearing in beaver ponds on the Copper River Delta, Alaska. *Canadian Journal of Fisheries and Aquatic Sciences* 63: 917-930.
- Hicks, B.J., M.S. Wipfli, D.W. Lang, and M.E. Lang. 2005. Marine-derived nitrogen and carbon in freshwater-riparian food webs of the Copper River Delta, southcentral Alaska. *Oecologia* 144: 558-569.
- Heintz, R.A., B.D. Nelson, J.P. Hudson., M. Larsen, L. Holland, and M.S. Wipfli. 2004. Marine subsidies in freshwater: Effects of salmon carcasses on the lipid class and fatty acid composition of juvenile coho salmon. *Transactions of the American Fisheries Society*. 133: 559-567.
- Wipfli, M.S., J.P. Hudson, J.P. Caouette, and D.T. Chaloner. 2003. Marine subsidies in freshwater ecosystems: salmon carcasses increase the growth rates of stream-resident salmonids. *Transactions of the American Fisheries Society*. 132: 371-381.
- Wipfli, M.S., J.P. Hudson, and J.P. Caouette. 1998. Influence of salmon carcasses on stream productivity: response of biofilm and benthic macroinvertebrates in southeastern Alaska, USA. *Canadian Journal of Fisheries and Aquatic Sciences*. 55: 1503-1511.

**Some additional relevant MDN papers include:**

- Bilby, R. E., B. R. Fransen, P. A. Bisson, and J. K. Walter. 1998. Response of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) to the addition of salmon carcasses to two streams in southwestern Washington, USA. *Canadian Journal of Fisheries and Aquatic Sciences* 55:1909-1918.
- Bilby, R. E., Fransen, B. R., Walter, J. K., Cederholm, C. J., and W. J. Scarlett. 2001. Preliminary evaluation of the use of nitrogen stable isotope ratios to establish escapement levels for Pacific salmon. *Fisheries* 26:6-14.
- Claeson, S. M., J. L. Li, J. E. Compton, and P. A. Bisson. 2006. Response of nutrients, biofilm, and benthic insects to salmon carcass addition. *Canadian Journal of Fisheries and Aquatic Sciences* 63:1230-1241.
- Jonsson, B., and N. Jonsson. 2003. Migratory Atlantic salmon as vectors for the transfer of energy and nutrients between freshwater and marine environments. *Freshwater Biology* 48:21-27.
- Nislow, K.H., and B.E. Kynard. 2009. The role of anadromous sea lamprey in nutrient and material transport between marine and freshwater environments. *Amer. Fish Soc. Symp.* 69:485-494.
- Rand, P. S., C. A. S. Hall, W. H. McDowell, N. H. Ringler, and J. G. Kennen. 1992. Factors limiting primary productivity in Lake Ontario tributaries receiving salmon migrations. *Canadian Journal of Fisheries and Aquatic Sciences* 49:2377-2385.

## Terrestrial prey subsidies

Another topic briefly discussed for possible inclusion in the final report was the trophic linkage between headwater streams and their riparian forests, and how this linkage affects the flow of terrestrial invertebrates from headwater streams to downstream habitats. This is another avenue thorough which headwater streams are connected to downstream waters. Below are a few references for the report that discuss terrestrial invertebrate subsidies to streams, which in turn contain further references the authors of the EPA report can decide on their inclusion.

- Allan, J. D., M. S. Wipfli, J. P. Caouette, A. Prussian, and J. Rodgers. 2003. Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. *Canadian Journal of Fisheries and Aquatic Sciences* 60:309-320.
- Baxter, C. V., K. D. Fausch, M. Murakami, and P. L. Chapman. 2007. Invading rainbow trout usurp a terrestrial prey subsidy to native char and alter their behavior, growth, and abundance. *Oecologia* 153:461-470.
- Baxter, C. V., K. D. Fausch, and W. C. Saunders. 2005. Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones. *Freshwater Biology* 50(2):201- 220.
- Kawaguchi, Y., and S. Nakano. 2001. Contribution of terrestrial invertebrates to the annual resource budget for salmonids in forest and grassland reaches of a headwater stream. *Freshwater Biology* 46:303-316.
- Kawaguchi, Y., S. Nakano, and Y. Taniguchi. 2003. Terrestrial invertebrate inputs determine the local abundance of stream fishes in a forested stream. *Ecology* 84(3):701-708.
- Mason, C. F., and S. M. MacDonald. 1982. The input of terrestrial invertebrates from tree canopies to a stream. *Freshwater Biology* 12:305-311.
- Nakano, S., H. Miyasaka, and N. Kuhara. 1999. Terrestrial-aquatic linkages: riparian arthropod inputs alter trophic cascades in a stream food web. *Ecology* 80(7):2435-2441.
- Richardson, J.S., Y. Zhang & L.B. Marczak. 2010. Resource subsidies across the land-freshwater interface and responses in recipient communities. *River Research and Applications* 26:55-66.
- Saunders, W. C., and K. D. Fausch. 2007. Improved grazing management increases terrestrial invertebrate inputs that feed trout in Wyoming rangeland streams. *Transactions of the American Fisheries Society* 136:1216-1230.

**William R. Wise, Ph.D.**  
Associate Professor  
Department of Environmental Engineering Sciences  
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Dr. Wise's pre-meeting comments are included in this report. Dr. Wise was unable to participate in the meeting and therefore was not able to prepare or submit post-meeting comments.



**Peer Review Meeting of EPA's Draft Report: Connectivity of Streams and Wetlands to Downstream Waters – A Review and Synthesis of the Scientific Evidence**

**Pre-Meeting Comments submitted by Dr. William R. Wise**

**TECHNICAL CHARGE QUESTIONS:**

1. This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.

- a) Are these conclusions supported by the scientific evidence?

Yes. The physical setting governs the types of material that can be transported to the downstream waters. This includes everything from the scale of chemicals and microorganisms to large woody debris, which provides important structure for a variety of aquatic species. Therefore, there is no question that all streams are physically, chemically, and biologically connected to the downstream waters, which might be rivers, estuaries, bays, springs, or aquifers. Ephemeral flow patterns should in no way be discriminated against because these often occur in regions where flashy events are capable of conveying quite a lot of matter to the receiving waters in a short period of time. Often, due to the different regime of the receiving water body (such as the velocity being greatly reduced), this matter will persist and affect the physical, chemical, and biological character of the receiving body.

- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing. All hydrology is local, so this is indeed a difficult question. The fact that the term karst does not appear in the glossary is of major concern to this reviewer. Karst systems deserve explicit mention when discussing the connection of water bodies because they often provide “out of sight-out of mind” conduits between seemingly unconnected waters and yet are direct exchange mechanisms for waters and their physical (mostly temperature), chemical, and biological properties. One reason that this issue deserves special consideration is that karst features usually suffer from an inability to attenuate water quality issues from one water body to another, as they do not filter the water as many other hydrologic connections can. One example of this is the Santa Fe River in North Central Florida. It sinks into the ground and reemerges over three miles later. This reviewer has applied a common surface water routing model, the Muskingum method, to the underground portion and found that it applies very well.

However, the water is underground; so is it a river? While this legal consideration exceeds the technical charge, it is worth noting that there remain important collaborative efforts to knit together technical and legal interpretations of the “colors of water.”

Karst systems are not unique to Florida but are prevalent in many states, such as Texas, Missouri, and Kentucky, to name a few.

- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.

The cited literature with which I had direct familiarity was well represented. Spot checking a few others for personal interest verified the same.

- 2. This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.

- a) Are these conclusions supported by the scientific evidence?

Yes. Open water and wetlands in riparian corridors provide important refugia for many species. They also, of course, provide conveyance of flow for extreme events. Their physical properties, such as vegetative nature and density are extremely important in governing the speed in which floods move through a system.

A class of streams known as deranged, where channels flow into wetlands and then back into channels is not specifically mentioned. In these systems, it can be difficult to know how to characterize the wetlands, even though there is no doubt of their connectivity to the system. This scenario should be mentioned although the impacts from the findings would not really change.

- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.

Again, all hydrology is local, so this is a difficult question. The cited literature does effectively address the issue, however.

- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.

The cited literature with which I had direct familiarity was well represented. Spot checking a few others for personal interest verified the same.

3. This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.

a) Are these conclusions supported by the scientific evidence?

These conclusions are both supported by the scientific literature and the extensive experience of this reviewer, who has worked in both what would be termed connected and isolated (hydrologically, not just geographically) wetlands.

b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.

Again, all hydrology is local, so this is a difficult question. The cited literature does effectively address the issue, however.

c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.

The cited literature with which I had direct familiarity was well represented. Spot checking a few others for personal interest verified the same.

4. This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.

a) Is this conclusion supported by the scientific evidence?

Yes. This is absolutely true. At any given point along a waterway, the watershed is defined as the locus of all points that drain to it. That one stream might seem minor is no reason to treat it differently than a larger stream. Smaller streams dominate geographically and need to be respected in the aggregate, as this conclusion states.

b) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.

Again, all hydrology is local, so this is a difficult question. The cited literature does effectively address the issue, however.

- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.

The cited literature with which I had direct familiarity was well represented. Spot checking a few others for personal interest verified the same.

## **Appendix B: Meeting Agenda**





# Peer Review Meeting for EPA's Draft Report: Connectivity of Streams and Wetlands to Downstream Waters - A Review and Synthesis of the Scientific Evidence

Washington, DC

Monday, January 30, 2012

## Agenda

8:00 AM      **Meeting Check in**

8:30 AM      **Welcome, Meeting Ground Rules & Logistics** ..... *Kate Schalk, ERG (Contractor)*

8:45 AM      **EPA Remarks** ..... *Laurie Alexander, EPA/ORD*

### REVIEWER INTRODUCTION AND DISCUSSIONS

9:00 AM      Discussion of Document Structure and Organization..... *Walter Dodds (Chair) & Reviewers*

9:30 AM      BREAK

9:45 AM      **Charge Question 1**..... *Walter Dodds (Chair) & Reviewers*

This report concludes that all streams, regardless of flow duration or size, are physically, chemically, and biologically connected to rivers; and these connections, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.

- a) Are these conclusions supported by the scientific evidence?
- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.
- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.

11:15 AM      **Charge Question 2**..... *Walter Dodds (Chair) & Reviewers*

This report concludes that open water and wetlands in riparian areas and floodplains of streams and rivers are physically, chemically, and biologically connected with the river network, and that their functions exert a strong influence on the character and functioning of downstream waters.

- a) Are these conclusions supported by the scientific evidence?
- b) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity *and* isolation? If not please indicate which references are missing.
- c) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.

## Agenda (cont'd.)

12:00 PM	LUNCH (on your own)
1:15 PM	<b>Charge Question 2 (discussion continues)</b> .....Walter Dodds ( <i>Chair</i> ) & Reviewers
1:45 PM	<b>Charge Question 3</b> .....Walter Dodds ( <i>Chair</i> ) & Reviewers <p>This report concludes that for non-riparian/non-floodplain wetlands that are not connected to the river network through a stream channel (i.e., geographically isolated wetlands and wetlands that spill into losing streams), connectivity and isolation vary within a watershed and over time, making it difficult to generalize about their connections to, or isolation from, downstream waters. The literature we reviewed does not provide sufficient information to evaluate the degree of connectivity (absolute or relative) of these non-riparian particular wetlands.</p> <ul style="list-style-type: none"> <li>d) Are these conclusions supported by the scientific evidence?</li> <li>e) Does the report include the most relevant peer-reviewed literature on these topics, including evidence of connectivity <i>and</i> isolation? If not please indicate which references are missing.</li> <li>f) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.</li> </ul>
3:15 PM	BREAK
3:30 PM	<b>Charge Question 4</b> .....Walter Dodds ( <i>Chair</i> ) & Reviewers <p>This report concludes that while the influence of a particular stream or wetland on downstream waters might be small, the aggregate contribution by an entire class of streams or wetlands (e.g., all ephemeral streams in the river network, or a cluster of small wetlands) might be substantial.</p> <ul style="list-style-type: none"> <li>d) Is this conclusion supported by the scientific evidence?</li> <li>e) Does the report include the most relevant peer-reviewed literature on this topic? If not please indicate which references are missing.</li> <li>f) Was the reviewed literature cited and summarized correctly? If not please indicate where correction or revision is needed.</li> </ul>
4:15 PM	<b>Review of Discussion Highlights</b> ..... Walter Dodds ( <i>Chair</i> ) & Reviewers
5:15 PM	<b>Closing Remarks</b> ..... Kate Schalk
5:30 PM	ADJOURN

## **Appendix C: List of Reviewers**



# Peer Review Meeting for EPA's Draft Report: Connectivity of Streams and Wetlands to Downstream Waters - A Review and Synthesis of the Scientific Evidence

Hilton Garden Inn –Downtown  
Washington, DC  
January 30, 2012

## Peer Reviewers

**David J. Cooper, Ph.D.**

Senior Research Scientist and Professor  
Department of Forest and Rangeland Stewardship  
Colorado State University  
Fort Collins, CO

**William G. Crumpton, Ph.D.**

Associate Professor  
Department of Ecology, Evolution  
& Organismal Biology  
Iowa State University  
Ames, IA

**Kenneth W. Cummins, Ph.D.**

Adjunct Professor  
Department of Fisheries Biology  
Humboldt State University  
Arcata, CA

**Walter K. Dodds, Ph.D. (Panel Chair)**

University Distinguished Professor  
Division of Biology  
Kansas State University  
Manhattan, KS

**James W. La Baugh, Ph.D.**

Hydrologist  
Office of Groundwater  
U.S. Geological Survey  
Reston, VA

**Mark C. Rains, Ph.D.**

Associate Professor  
Department of Geology  
University of South Florida  
Tampa, FL

**John S. Richardson, Ph.D.**

Professor  
Department of Forest Sciences  
University of British Columbia  
Vancouver, BC, Canada

**Joel W. Snodgrass, Ph.D.**

Chair, Department of Biological Sciences  
Towson University  
Towson, MD

**Arnold van der Valk, Ph.D.**

Professor  
Department of Ecology, Evolution  
& Organismal Biology  
Iowa State University  
Ames, IA

**Mark S. Wipfli, Ph.D.**

Professor  
Cooperative Fish & Wildlife Research Unit  
U.S. Geological Survey  
Fairbanks, AK

**William R. Wise, Ph.D.**

(Unable to Participate in Meeting)  
Associate Professor  
Department of Environmental Engineering Sciences  
University of Florida  
Gainesville, FL



## **Appendix D: List of Observers**





## List of Observers

<b>EPA</b>
Rebecca Aicher, AAAS Fellow, U.S. Environmental Protection Agency, Washington, DC
Laurie Alexander, U.S. Environmental Protection Agency, Washington, DC
Donna Downing, U.S. Environmental Protection Agency, Washington, DC
Rachel Fertik, U.S. Environmental Protection Agency, Washington, DC
Scot Hagerthey, U.S. Environmental Protection Agency, Washington, DC
Rose Kwok, U.S. Environmental Protection Agency, Washington, DC
Stephen LeDuc, U.S. Environmental Protection Agency, Washington, DC
Jim Pendergast, U.S. Environmental Protection Agency, Washington, DC
Amina Pollard, U.S. Environmental Protection Agency, Washington, DC
Hadas Raanan-Kiperwas, ORISE Fellow, U.S. Environmental Protection Agency, Washington, DC
Caroline Ridley, U.S. Environmental Protection Agency, Washington, DC
Mark Ryan, U.S. Environmental Protection Agency, Boise, ID
Kate Schofield, U.S. Environmental Protection Agency, Washington, DC
Michael Slimak, U.S. Environmental Protection Agency, Washington, DC

<b>USACE</b>
David Lekson, U.S. Army Corps of Engineers, Wilmington, NC
Robert Lichvar, U.S. Army Corps of Engineers, Hanover, NH
Karen Mulligan, U.S. Army Corps of Engineers, Washington, DC

<b>EPA – VIA TELECONFERENCE</b>
Ken Fritz, U.S. Environmental Protection Agency, Cincinnati, OH
William Kepner, U.S. Environmental Protection Agency, Las Vegas, NV
Charles Lane, U.S. Environmental Protection Agency, Cincinnati, OH
Michael McManus, U.S. Environmental Protection Agency, Cincinnati, OH
Scott Leibowitz, U.S. Environmental Protection Agency, Corvallis, OR
Jim Wigington, U.S. Environmental Protection Agency, Corvallis, OR

<b>USACE – VIA TELECONFERENCE</b>
Sally Yost, U.S. Army Corps of Engineers, Vicksburg, MS
Dan Smith, U.S. Army Corps of Engineers, Vicksburg, MS

# Congress of the United States

## House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

2321 RAYBURN HOUSE OFFICE BUILDING

WASHINGTON, DC 20515-6301

(202) 225-6371  
www.science.house.gov

November 6, 2013

Howard Shelanski  
Administrator,  
Office of Information and Regulatory Affairs  
Office of Management and Budget  
Executive Office of the President  
725 17<sup>th</sup> Street, NW  
Washington, DC 20503

Dear Mr. Shelanski:

The Office of Management and Budget (OMB) plays a pivotal role in ensuring that agencies follow the law. Executive Order (EO) 12866 assigns the OMB's Office of Information and Regulatory Affairs (OIRA) the responsibility of coordinating interagency review of rulemaking to assure that the regulations are consistent with applicable law and the EO's principles, which include incorporating public comment, considering alternatives to the rulemaking, and analyzing both costs and benefits. This oversight is designed to promote balanced evaluation of agency rulemaking. As the Environmental Protection Agency (EPA) expands its Clean Water Act (CWA) jurisdiction, OMB needs to ensure full evaluation and compliance with the Executive Order and the law.

Rather than allowing time for a review of their proposed regulations, the EPA is rushing forward regardless of whether the science actually supports the rule. This rule could represent a dramatic expansion of EPA's authority to include isolated wetlands, streams and ditches. Such unrestrained federal intrusion poses a serious threat to private property rights, state sovereignty and economic growth.

On September 17, 2013, EPA sent a draft rule to your office for interagency review. The draft rule would redefine "waters of the United States" under the CWA. On the same day, EPA submitted a draft scientific assessment to its Scientific Advisory Board (SAB) for peer review. The draft "Connectivity Report"<sup>1</sup> evaluates the significance of potential connections between isolated streams and wetlands with navigable waters. EPA explained that "[f]indings from this Report will help inform EPA

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<sup>1</sup> *Draft Science Synthesis Report on the Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*

and the U.S. Army Corps of Engineers in their continuing policy work and efforts to clarify what waters are covered by the [CWA].” However, although EPA claims this Report will provide the bedrock for this rulemaking, EPA sent the rule to OMB before the science was reviewed.

In accordance with OMB requirements, the Connectivity Report must be fully and openly peer reviewed before interagency review of the draft rule. Further, after peer review of the underlying science, OMB should ensure that EPA provides the SAB with the draft rule during the interagency review process. Specifically, the law requires that when CWA proposals are “provided to any other Federal agency for formal review and comment, [EPA] shall make available to the [SAB] such proposed criteria document, standard limitation, or regulation, together with relevant scientific and technical information in the possession of the Environmental Protection Agency on which the proposed action is based.”<sup>2</sup> Despite this statutory requirement, the SAB has not been asked to review the draft CWA rule that is undergoing peer review.<sup>3</sup>

The need for OMB to ensure that the statutory peer review process is followed is underscored by the fact that these are “highly influential” scientific documents as that term is defined in OMB’s 2004 *Peer Review Bulletin* (“OMB Bulletin”).<sup>4</sup> Because the Report and the draft rule “have a potential impact of more than \$500 million in any one year on either the public or private sector or that the dissemination is novel, controversial, or precedent-setting, or has significant interagency interest,” both trigger the OMB definition requiring an additional level of review. Further, according to your Office’s list of EPA regulations currently under review, the draft rule is considered “economically significant” and there is no legal deadline for completion of interagency review.<sup>5</sup> EPA also confirmed that the Report is “highly influential” in a June 27, 2012 letter to the Committee.<sup>6</sup>

“Highly influential” scientific documents must be peer reviewed *early* in the rulemaking process. Specifically, the OMB Bulletin states that “it is important to obtain peer review before the agency announces its regulatory options so that any technical corrections can be made before the agency becomes invested in a specific approach or the positions of interest groups have hardened.” Significantly, the Bulletin notes that if the review occurs too late in the process “it is unlikely to contribute to the course of a rulemaking” and that investing in peer review early will increase net benefits by reducing the likelihood of litigation. We agree.

Transparent peer review of scientific assessments is a prerequisite to the rulemaking process. Just last year, EPA assured the Science Committee that it would release the study in a manner sufficient to “provide the agencies and the public with data

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<sup>2</sup> *Environmental Research, Development and Demonstration Authorization Act of 1978*, 42 USC § 4365.

<sup>3</sup> [http://science.house.gov/sites/republicans.science.house.gov/files/documents/Letters/101813\\_letter.pdf](http://science.house.gov/sites/republicans.science.house.gov/files/documents/Letters/101813_letter.pdf)

<sup>4</sup> <http://www.whitehouse.gov/sites/default/files/omb/assets/omb/memoranda/fy2005/m05-03.pdf>

<sup>5</sup> <http://www.reginfo.gov/public/jsp/EO/eoDashboard.jsp>

<sup>6</sup> <http://science.house.gov/sites/republicans.science.house.gov/files/documents/06-27-2012%20EPA%20to%20Harris%20re%20CWA.pdf>

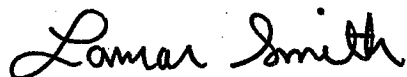
and information relevant to this rulemaking” and the opportunity for meaningful public comment.

By rushing through this process, the Agency not only violates the law, but ignores its commitments to Congress and the American people. This rushed rulemaking is a clear attempt to rubber stamp the pre-determined regulatory agenda.

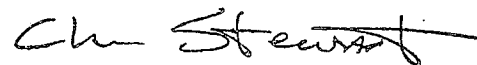
Your office should not complete the interagency review of the draft rule until both the draft Connectivity Report and the draft rule on CWA jurisdiction have been fully and openly peer reviewed. This will allow sufficient time for offices participating in the interagency review process to reflect on the SAB peer review comments.

Putting the regulatory cart before the scientific horse is a direct violation of the EPA’s pledge to make “sound science and public participation the backbone of our rulemaking efforts.”<sup>7</sup> The proposed rule could give the EPA unprecedented power over private property in the U.S. Racing through the approval process without proper peer review and transparency amounts to an EPA power play to regulate America’s waterways.

Sincerely,



Rep. Lamar Smith  
Chairman  
Committee on Science, Space,  
and Technology



Rep. Chris Stewart  
Chairman  
Subcommittee on Environment

cc: Rep. Eddie Bernice Johnson, Ranking Member, Committee on Science, Space, and Technology  
Rep. Suzanne Bonamici, Ranking Member, Subcommittee on Environment, Committee on Science, Space, and Technology  
The Honorable Gina McCarthy, Administrator, EPA  
Lieutenant General Thomas Bostick, Commanding General and Chief of Engineers, US Army Corps of Engineers  
Dr. David Allen, Chair, EPA Science Advisory Board  
Dr. Amanda Rodewald, Chair, EPA Science Advisory Board Panel for the Review of the EPA Water Body Connectivity Report  
Mr. Christopher Zarba, Director, EPA SAB Staff Office

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<sup>7</sup> Ibid.

# Congress of the United States

## House of Representatives

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November 6, 2013

Dr. Amanda Rodewald, Chair, Science Advisory Board Panel for the Review of the EPA Water Body Connectivity Report

Dr. David Allen, Chair, EPA Science Advisory Board

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, NW

Washington, DC 20460

Dear Drs. Rodewald and Allen:

On September 17, 2013, the Environmental Protection Agency (EPA) announced the availability of the Draft Science Synthesis Report on the Connectivity of Streams and Wetlands to Downstream Waters (Draft Connectivity Report or Report), which synthesizes the peer-reviewed scientific literature on the connectivity of streams and wetlands relative to downstream waters.<sup>1</sup> On the same day, EPA also announced that it had sent a proposed rule on the scope of Clean Water Act (CWA) jurisdiction to the Office of Management and Budget (OMB) for interagency review. EPA states that the Report's findings will inform the upcoming rulemaking on CWA jurisdiction.

Along with the Report, EPA released technical charge questions to the Science Advisory Board (SAB) expert panel who will conduct a peer review of the Report.<sup>2</sup> EPA's charge questions are focused on verifying the technical accuracy of the Report's findings that streams and most wetlands are connected to downstream waters. EPA does not, however, ask the important questions about the significance of these connections to the health or integrity of downstream waters. It is critical that the SAB panel address such important scientific questions, including identification of key limitations or uncertainties in the science. The answers to these questions will assist policy makers in clarifying the scope of CWA jurisdiction over waters of the United States.

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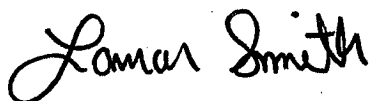
<sup>1</sup> Notice Announcing Release of Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (External Review Draft) (Sept. 17, 2013), available at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=238345>.

<sup>2</sup> SAB, Connectivity of Streams and Wetland to Downstream Waters: A Review and Synthesis of the Scientific Evidence, Technical Charge to External Peer Reviewers, available at <http://yosemite.epa.gov/sab/sabproduct.nsf/02ad90b136fc21ef85256eba00436459/7724357376745f48852579e60043e88c!OpenDocument>.

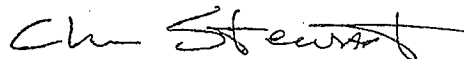
Pursuant to our authority under the Environmental Research, Development and Demonstration Authorization Act (ERDDAA), the Committee on Science, Space, and Technology is providing the SAB Panel for the Review of EPA's Water Body Connectivity Report and SAB additional charge questions related to the Report. Mindful of the unique role created for the Committee under the statute, we anticipate a robust examination of the issues encompassed in the charge questions.

We request that the SAB Panel for the Review of EPA's Water Body Connectivity Report and the SAB respond to the additional charge questions set forth below.

Sincerely,



Rep. Lamar Smith  
Chairman  
Committee on Science, Space,  
and Technology



Rep. Chris Stewart  
Chairman  
Subcommittee on Environment

cc: Rep. Eddie Bernice Johnson, Ranking Member, Committee on Science, Space, and Technology  
Rep. Suzanne Bonamici, Ranking Member, Subcommittee on Environment, Committee on Science, Space, and Technology  
The Honorable Gina McCarthy, Administrator, EPA  
Mr. Christopher Zarba, Acting Director, SAB Staff Office  
Ms. Iris Goodman, SAB Designated Federal Officer  
Dr. Thomas Armitage, SAB Designated Federal Officer

## Charge Questions of the Science, Space, and Technology Committee for EPA's SAB Review of the Draft Connectivity Report

### Background

The CWA regulates “navigable waters” defined as “waters of the United States.” 33 U.S.C. §§ 1344, 1362(7). The United States Supreme Court has examined the meaning of this statutory language three times. In *United States v. Riverside Bayview Homes, Inc.*, 474 U.S. 121 (1985), the Supreme Court upheld the regulation of wetlands adjacent to navigable waters because it found that the adjacent wetlands were “inseparably bound up” with the navigable waters. In *Solid Waste Agency of N. Cook Cnty v. U.S. Army Corps of Eng'rs*, 531 U.S. 159 (2001) (“*SWANCC*”), the Supreme Court rejected the assertion of jurisdiction over isolated ponds because they lacked a significant nexus to navigable waters. After *SWANCC*, the government asserted that the *SWANCC* decision applied only to isolated waters and that if a water “connected” to navigable waters, it was not an isolated water and could therefore be regulated as a navigable water under the CWA.<sup>3</sup> This “any connection” theory essentially reached all wet areas, including ditches, drains, desert washes, and ephemeral waters that flow infrequently and are far removed from traditional navigable waters.

In *Rapanos v. United States*, 547 U.S. 715 (2006), the Supreme Court heard two consolidated cases involving the assertion of CWA jurisdiction over sites with nearby drains and ditches based on the agencies’ determination that the sites were connected to tributaries of navigable waters. A majority of the Justices, looking at the statutory language, rejected this “any connection” theory of jurisdiction, finding it was too broad a standard. The plurality held that the plain language of the CWA “does not authorize this ‘Land Is Waters’ approach to federal jurisdiction” and that “[i]n applying the definition to ephemeral streams, wet meadows, storm sewers and culverts, directional sheet flow during storm events, drain tiles, manmade drainage ditches, and dry arroyos in the middle of the desert, the Corps has stretched the term ‘waters of the United States’ beyond parody.” 547 U.S. at 734 (internal quotations omitted). Instead, the plurality held that the CWA “confers jurisdiction over only relatively *permanent* bodies of water.” *Id.* (emphasis in original).

Justice Kennedy also criticized the Corps’s standard as too broad because it “leave[s] wide room for regulation of drains, ditches, and streams remote from any navigable-in-fact water and carrying only minor water volumes . . . .” 547 U.S. at 781 (Kennedy, J., concurring). In his *Rapanos* concurrence, Justice Kennedy established a “significant nexus” standard. *Id.* at 780. Justice Kennedy noted that consideration of “the quantity and regularity of flow” and proximity to traditional navigable waters is important for assessing whether there is a significant nexus. *Id.* at 786. Accordingly, following the *Rapanos* decision, identifying which waters have a **significant** nexus, not just **a** nexus, is critical.

Noting on several occasions that the reach of the CWA is notoriously unclear, the Supreme Court also called on the agencies to do a rulemaking and clarify key jurisdictional

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<sup>3</sup> See, e.g., Brief for the United States at 31, *Rapanos v. United States*, 547 U.S. 715 (2006) (No. 04-1034); *Rapanos*, 547 U.S. at 780 (Kennedy, J., concurring) (“The Corps’ theory of jurisdiction in these consolidated cases—adjacency to tributaries, however remote and insubstantial—raises concerns ....”).

standards.<sup>4</sup> Specifically, Justice Kennedy noted that the presence of an ordinary high water mark is not a reliable standard for determining whether a water is a jurisdictional tributary. *Rapanos*, 547 U.S. at 781.<sup>5</sup> Indeed, the regulated public similarly has long called for a rulemaking to clarify the reach of the CWA and define key jurisdictional terms such as “tributary” and “adjacent.”

The agencies have stated that this report “will provide the scientific basis needed to clarify CWA jurisdiction” and “will inform [the] upcoming joint USEPA/Army Corps of Engineers rulemaking to enhance protection of the chemical, physical, and biological integrity of our nation’s waters . . . .”<sup>6</sup> Therefore, the Committee on Science, Space, and Technology believes that it is critical for the charge questions to be focused on the relevant issues that have been plaguing the agencies and the public for decades.<sup>7</sup> Accordingly, with this background in mind, we ask that the SAB Panel for the Review of EPA’s Water Body Connectivity Report and the SAB respond to the following questions:

### Quantification of “Significant Nexus”

The report concludes that all streams and most wetlands are connected to downstream waters. It does not appear that the report evaluates anything more than the presence of connectivity among “waters.” The real question, however, is the scientific significance of these connections on downstream traditional navigable waters.

- Does the science provide a method to establish whether connections are significant? What specific metrics can be used to determine if a measured connection (chemical, physical, or biological) significantly influences the health or integrity of a downstream water body?
- How will a “significance” threshold be determined? How will agencies be able to quantify that an upstream water body exerts a significant influence on the health or integrity of a downstream traditional navigable water, as opposed to merely a measured connection?
- Should the frequency and duration of flow and proximity to navigable waters play a role in determining the significance of a connection? If so, how?
- Are there key limitations or uncertainties in establishing scientific significance of connectivity?

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<sup>4</sup> See, e.g., *Rapanos*, 547 U.S. at 726 (plurality); *id.* at 782 (Kennedy, J., concurring); *id.* at 758 (Roberts, C.J., concurring); *Sackett v. EPA*, 132 S. Ct. 1367, 1375 (2012) (Alito, J., concurring).

<sup>5</sup> See also Matthew K. Mersel, U.S. Army Corps of Engineers, *The Ordinary High Water Mark: Concepts, Research, and Applications* (Mar. 20, 2013) (acknowledging that Corps standard for identifying streams is “vague” and has been applied “inconsistently”).

<sup>6</sup> Notice Announcing Release of Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (External Review Draft) (Sept. 17, 2013), available at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=238345>.

<sup>7</sup> See U.S. Gen. Accounting Office, GAO-04-297, *Waters and Wetlands: Corps of Engineers Needs to Evaluate Its District Office Practices in Determining Jurisdiction* at 12-16 (Feb. 2004) (hereinafter, GAO Report).

## Defining "Stream"

In its glossary, the report defines a stream as "a relatively small volume of flowing water within a visible channel, including subsurface water moving in the same direction as the surface water, and lateral flows exchanged with associated floodplain and riparian areas." Draft Connectivity Report at A-17. Then, it finds that "[a]ll tributary streams, including perennial, intermittent, and ephemeral streams, are physically, chemically, and biologically connected to downstream rivers." *Id.* at 1-6.

- What is the scientific basis for including subsurface groundwater in the definition of "stream"?
- What is the scientific basis for including overland flows in floodplain areas in the definition of "stream"?
- Does the science support the point that all streams (channels that carry water) have a *significant* nexus to traditional navigable waters? Does the science establish that serving as a conduit or channel for rainwater or stormwater is sufficient to be classified as a stream? If so, explain.
- What is the difference between a stream (under the report's definition) and a roadside or agricultural ditch?
- Is there scientific evidence that evaluates the performance of ditches? If so, do a majority of ditches perform the entire suite of functions performed by streams?
- How should frequency and duration of flow and proximity to navigable waters be considered in assessing whether a feature should be classified as a stream?

## Isolated Waters

The report discusses "geographically isolated wetlands," which it defines as "wetland[s] that [are] completely surrounded by uplands." Draft Connectivity Report at A-6. The report notes that "'geographic isolation' should not be confused with functional isolation, because geographically isolated wetlands can still have hydrological and biological connections to downstream waters." *Id.* at 1-12.

- Does the science establish specific metrics to determine if a "geographically isolated water" exerts a significant influence on the health or integrity of a downstream traditional navigable water body?
- Did the peer-reviewed studies examined with respect to wetlands evaluate features which met the Cowardin definition of "wetland" or the Federal regulatory definition of "wetland"?
- Under the Cowardin definition, an area is classified as a wetland if it has one or more of three characteristics: hydrology, hydrophytes, and hydric soils. Under the Federal regulatory definition, however, an area must exhibit all three characteristics to be classified as a wetland. Is it appropriate for this report to rely on the broader Cowardin definition of "wetland" rather than the Federal regulatory definition?
- Is it appropriate for this report, which defines "geographically isolated wetland" as "a wetland that is completely surrounded by uplands," *id.* at A-6, to rely on the narrower Cowardin concept of "upland" rather than the Federal regulatory understanding?
- The report identifies a number of functions served by unidirectional wetlands, including acting as sinks and transformers for various pollutants and offering biological

connectivity to downstream waters. *Id.* at 1-12. Which of these functions are also served by the uplands adjacent to and nearby the unidirectional wetlands?

- The report identifies a study reflecting that, in a 4-year period, nearly 20% of the precipitation that fell on a wetland complex in a Texas coastal plain flowed as surface runoff to a nearby waterway. *Id.* at 1-12. Do other studies show that surface runoff also flows across upland features into nearby waterways? Do these and other studies also show that some of the water that is not transferred to nearby waterways as surface runoff is transferred as groundwater? What is the significance of the hydrological connectivity between these uplands and downstream waters like that noted by the report in the last sentence of item “d” on page 1-12?
- The report notes that infrequent events, such as large floods, temporarily connect nearby or distant streams or wetlands to rivers and can therefore have large, long-lasting effects. *Id.* at 1-5. Do these infrequent, large flood events also connect uplands with those same streams in the same fashion?

### **Navigable Waters**

Under Justice Kennedy’s “significant nexus” standard, features are jurisdictional only where the feature has a significant nexus with “traditional navigable waters.”

- Does the science look at connectivity with “traditional navigable waters” or merely downstream waters?

### **Site-Specificity and Regional Variability**

The effects of a tributary on the downstream waters vary over time and between tributaries as a result of the differences in water volume, sediment characteristics, and water quality. These variations are largely an effect of the differences in the size of the tributary relative to the downstream waters. The report acknowledges that “[c]limate, watershed topography, soil and aquifer permeability, the number and types of contributing waters, their spatial distribution in the watershed, interactions among aquatic organisms, and human alteration of watershed features, among other things, can act individually or in concert to influence stream and wetland connectivity to, and effects on, downstream waters.” Draft Connectivity Report at 1-5. Although the report attempts to address regional variability using several case studies for particular regions and features, it draws sweeping, broad conclusions.

- Given the substantial variability in the influence of any given tributary on any particular water, does the science support making generalizations about tributary impacts on water quality?
- Does the science support making predictions about stream impacts across regions? If so, explain.
- Should such an approach be broadly applied within a region, or is it more accurate for determinations to be made on a site-specific basis? If so, when and under what circumstances?
- How will metrics that are used to measure connectivity be calibrated or modified for application to various classes of waters in different geographic regions or even distinct watersheds within geographic regions?

- Does the science support making presumptions that all streams in a region or of the same class perform the same functions given the substantial variability among parameters such as stream size, discharge, and physical or ecological contribution to downstream waters? If so, explain.
- The report determines that there is "a gradient of hydrologic connectivity-isolation with respect to river networks, lakes, or marine/estuarine water bodies" and that "the existence of this gradient among wetlands of the same type or in the same geographic region can make it difficult to determine or generalize, from the literature alone, the degree to which particular wetlands (individually or as classes), including geographically isolated wetlands, are hydrologically connected." *Id.* at 1-12. If generalization is not possible in the context of isolated waters due to the variety of factors that affect contribution to downstream waters, and as noted on p. 1-5 there are numerous factors resulting in variability in the contributions of streams to downstream waters, how can the report generalize about the degree to which particular streams are connected?
- What does the scientific data show is the range of variability for ephemeral streams for each of the factors that influence stream connectivity to downstream waters, including climate, nutrient processing, water storage, habitat, ecology, frequency and duration of flow, and proximity to traditional navigable waters? For intermittent streams? For perennial streams?

### **Temporal Variability**

Watershed science recognizes seasonal and year-to-year variation in flow and climate. Studies have also concluded that the results of watershed-specific studies cannot be generalized to all regions due to differences in vegetation, geology (e.g., slope), the amount of detritus and invertebrates exported downstream, and climate. Others note that the suitability of a hydrological connection as a biological connection varies among species and also on a regional or even local basis. The report acknowledges, "Since rivers develop and respond over time and are functions of the whole watershed, understanding the integration of contributions and effects over time is also necessary to have an accurate understanding of the system, taking into account the duration and frequency of material export and delivery to downstream waters." Draft Connectivity Report at 1-14. The report acknowledges regional variability and provides several case studies for particular areas, but its broad conclusions do not account for temporal variability.

- Given that seasonal and year-to-year variation in flow and climate exist, and that those variations affect physical, chemical, and ecological processes, how do determinations of connectivity account for the temporal variation in physical, chemical, and biological processes?
- To enable determinations of connectivity for any given system, are measurements over the course of multiple seasons or years required? If made at a single time point or in a single year, will the determination be considered relevant and applicable indefinitely, or will some periodic review be required?

### **Draft CWA Rule**

According to ERDDAA: "The Administrator, at the time any proposed criteria document, standard, limitation, or regulation under the... Federal Water Pollution Control Act

[33 U.S.C. 1251 et seq.]... is provided to any other Federal agency for formal review and comment, shall make available to the Board such proposed criteria document, standard, limitation, or regulation, together with relevant scientific and technical information in the possession of the Environmental Protection Agency on which the proposed action is based.... The Board may make available to the Administrator, within the time specified by the Administrator, its advice and comments on the adequacy of the scientific and technical basis of the proposed criteria document, standard, limitation, or regulation, together with any pertinent information in the Board's possession."

- Pursuant to ERDDAA, have you been provided a copy of the EPA's draft rule to clarify jurisdiction of the Clean Water Act?
- If no, does support or approval of the Draft Connectivity Report constitute support or approval of EPA's draft rule by the Science Advisory Board or the Panel for the Review of the EPA Water Body Connectivity Report?